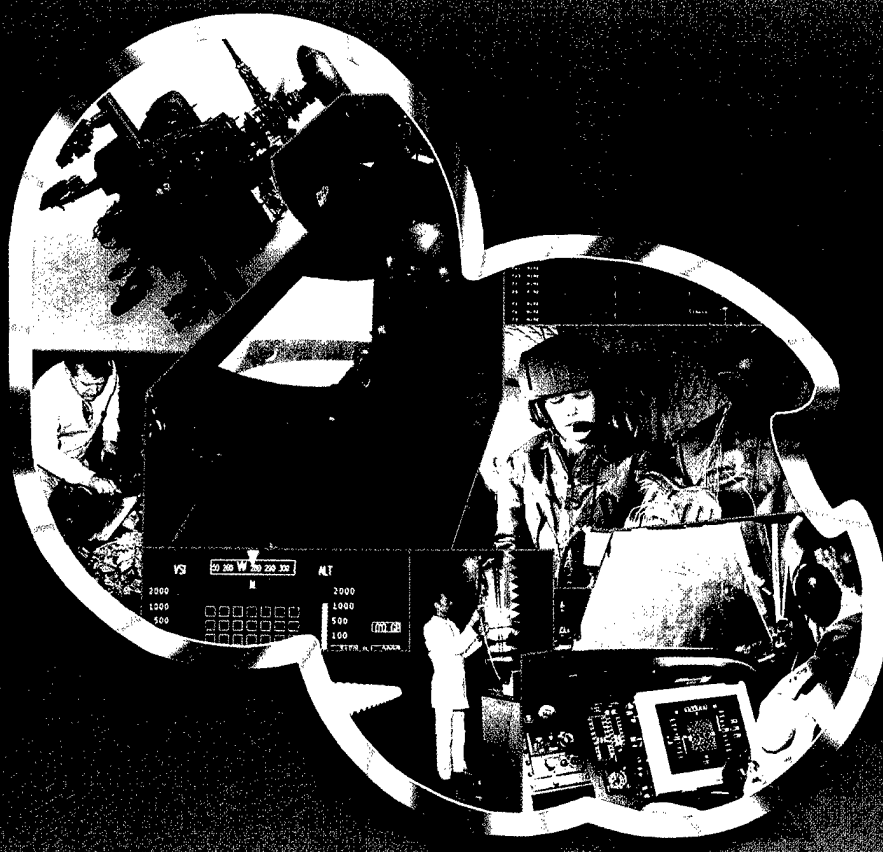USAARL Report No. 2002-10

Corneal Shape and Visual Performance after Keratorefractive Surgery (Reprint)

by Corina van de Pol

Aircrew Health and Performance Division

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Patients were generally satisfied with their outcomes, despite measurable deficits in visual performance, however the few cases of unfavorable outcomes point to the need for strict evaluation of any procedure, especially when the procedure is elective. Recommended analysis includes visual performance beyond Snellen, and the impact of the procedure on ocular optics, clarity and mechanical stability.

Abstract

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by

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Doctor of Philosophy in Vision Science

University of California, Berkeley

Professor Stanley A. Klein, Chair

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Professor Brian A. Barsky

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Chapter 1

Introduction

1.1 Background and Aim of Study

Refractive surgery is gaining increased acceptance as an alternative to glasses and contact lenses for the correction of refractive error [1]. The most significant technological gain for this acceptance is the development of the excimer laser as an instrument to reshape the cornea. Refractive surgery is not a new concept, having been suggested by Bates over 100 years ago [2]. However, it was not until the advent of radial keratotomy (RK) in the 1970's that refractive surgery entered the popular mainstream [3, 4]. RK could reduce myopia with as few as four radial incisions of the anterior cornea, and visual recovery after RK was more immediate than more invasive techniques such as epikeratophakia or anterior lamellar keratoplasty (ALK). More incisions of the cornea could be made where insufficient refractive correction was achieved to decrease corneal curvature, although this practice was not always successful [5]. Overcorrections, which left the patient hyperopic, were not correctable in this manner and often meant returning to contact lens or spectacle wear.

The Prospective Evaluation of Radial Keratotomy (PERK) study is the most comprehensive study of RK results to date. PERK and other studies found that the most significant consequences of RK were unpredictability of results, diurnal fluctuations of refraction, long-term progression towards hyperopia, and

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visual disturbances including haloes and glare [6-16]. Based on these findings

and the possibility of more accurate techniques on the horizon, there was a rapid

decline in the demand for RK procedures into the early 1990's.

In the United States, the excimer laser for photorefractive keratectomy

(PRK) officially emerged as an alternative to RK, with FDA approval of the first

laser system in October 1996. The precision of laser ablation of corneal tissue

versus manual incisions held the promise of more accurate outcomes with less

fluctuation of refraction [17-19]. Studies of refractive outcomes have shown an

improvement in the accuracy and stability of laser procedures such as PRK over

RK [20-28]. A main reason why PRK is more stable than RK is that the RK

procedure cuts more deeply into the cornea and weakens the capability of the

cornea to maintain its shape [29]. Haloes and glare experienced by patients after

RK were thought to be less likely after PRK since there would be no radial

incisions on the cornea encroaching within the pupil area. However, symptoms

of halos and glare with PRK have been documented [30-35].

The search for other causes of visual disturbances has led to numerous

studies of the changes in corneal optics and clarity after PRK. Changes in

corneal shape, specifically an alteration in the spherical aberration balance of the

eye, have been identified in studies of both RK and PRK [36-39]. Corneal haze

which develops in the healing process after PRK may also contribute to

increased light scatter and decreased contrast sensitivity or increased symptoms

of glare [34, 40-55]. Patients also report vague symptoms of visual disturbance

related to ambient light levels after PRK, such as difficulties driving at dusk or

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dawn and a decrease in ability to see detail in low light conditions. These symptoms are similar to those experienced by patients with early cataract or corneal edema where the presence of media opacities decreases contrast sensitivity [56-62]. Corneal haze, then, becomes suspect as the source of these visual difficulties after PRK. However, contrast sensitivity is decreased among RK patients as well [10, 63-66]. Unless the decrease is due entirely to scattered light from the radial incisions used in RK, corneal shape changes are again suspect. It becomes clear there are many issues to address in terms of the assessment of visual outcomes after excimer laser surgery.

This dissertation will focus on three inter-related issues: visual performance, corneal clarity and corneal shape. In general terms, the concepts and recommendations will apply to any form of refractive surgery that modifies corneal shape. The first factor to consider is whether there are measures of visual performance that are sensitive to the subtle visual changes reported by refractive surgery patients. Snellen acuity and other measures of high contrast acuity continue to be the standard of visual assessment in clinical practice across a wide range of clinical conditions [67-75]. Snellen acuity primarily endures because it has existed for over one hundred years and has become part of professional and layman communication around most of the world [76]. However, high contrast acuity may not be enough for assessment of refractive surgery outcomes. High contrast acuity has been shown to underestimate the effect of cataracts [56-58] and it potentially overestimates the visual outcomes of

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refractive surgery. This is evidenced by the reports of symptoms of visual disturbance despite excellent best-corrected Snellen acuities [77-82].

There are many methods to evaluate decreased contrast sensitivity or acuity. Using sine wave gratings with variable spatial frequency and contrast is perhaps the most accurate method, but the duration of the task and special equipment required make it impractical for clinical use. Charts that use sine wave gratings simplify the procedure but present an unfamiliar task for the patient [83-87]. Letter charts with either a fixed contrast level and decreasing letter size or a fixed letter size and decreasing contrast level are also available [88-92]. A letter chart is easier for patients to complete and requires very little additional set up for the clinician. The most difficult aspect of using a letter chart is determining which chart is appropriate for the anticipated contrast sensitivity loss. Currently, no single letter chart is sufficient to determine a generalized depression of the contrast sensitivity function. Rather, they are best suited for measuring performance decrements at a specific region of the function. Studies of the contrast sensitivity function after PRK have indicated mild depression in the higher spatial frequencies [49, 77, 78, 93-97].

For my study I chose the Rabin Small Letter Contrast Test, a chart with high spatial frequency letter size and decreasing contrast level. [98]. The details of its use and the results of my evaluation of a specific group of refractive surgery patients are presented in Chapter 2.

The second factor to consider is the effect of corneal clarity on visual performance. After surface excimer procedures such as PRK, corneal epithelial

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and anterior stromal healing over the ablation zone is only somewhat predictable [42, 46, 52, 99-101]. This can result in loss of desired effect or development of subepithelial haze [51, 55, 102-104]. Corneal haze is evaluated in terms of its effect on high contrast acuity and letter contrast sensitivity in Chapter 3.

The third major factor is the analysis of how corneal shape changes are related to the subtle visual changes refractive surgery patients experience. What actually happens when the shape of the corneal surface is changed? Without going into too much detail here, as the principles of laser refractive surgery are presented later in this chapter, the subtraction of tissue is not without consequence. There are changes in the aberration structure of the cornea and hence the aberration balance of the eye is disturbed [37, 38, 105-107]. The ablation does not involve the whole cornea so there is a necessary transition zone of rapid curvature change between the ablation zone and the peripheral unablated cornea [108]. The optical consequences of the transition zone depend on its relationship to the entrance pupil of the eye. If the region of rapid curvature change is within the bonds of the entrance pupil, either due to a small ablation zone or a large pupil, a great increase in spherical aberration is expected [109]. If the ablation is decentered, more complex aberrations are expected. The significance of these aberrations, how they are described and how they relate to visual performance is found in Chapter 4, the main chapter of this thesis.

Chapter 4 addresses three questions:

- Can letter contrast sensitivity be predicted using existing topographic indices?

- Are there characteristics of the ablation zone and/or transition zone that relate to visual performance?

- What aspects of the point spread function relate to the visual outcomes after refractive surgery?

The chapter begins with an evaluation of corneal shape changes using existing topographic indices available on the TMS-2™ videokeratograph (software version W1.2, Computed Anatomy, Inc.). It continues with the assessment of the corneal refractive power to determine quantitative measures of ablation centration and size and how these impact vision. Finally, the image forming properties of the corneal surface will be determined in terms of the point spread function and the modulation transfer function. The effects of induced aberrations on changes in visual performance will then be analyzed.

Chapter 5 looks at keratorefractive surgery from the patient's perspective. What it is like to go through the procedure and the healing period that follows. How vision after the procedure differs from before the procedure. How patients after refractive surgery rate their vision under certain conditions compared to normals. Chapter 5 further summarizes the overall findings of this dissertation and lays the foundation for a recommended scheme to evaluate outcomes of any keratorefractive procedure, whether it involves the use of an excimer laser or any other technology. The data for all subjects are provided in Appendix A.

Before going into the various studies, some concepts of corneal topography are reviewed in Section 1.2. The pros and cons of traditional methods of correcting refractive error are covered in Section 1.3. More details on the concepts of refractive surgery in general and laser refractive surgery in particular are provided in Section 1.4. Measures of refractive surgery outcomes are reviewed in the last section of this chapter.

1.2 Measurement of the Cornea

Much of the work in this dissertation depends on the ability to measure the shape of the corneal surface. The unique structure of the cornea allows for measurement using principles of reflection, since it basically acts as a convex mirror. Objects of known dimensions and distances produce virtual images of variable size depending on the reflective power of the surface. Therefore, basic optical principles can be applied to determine the radius of curvature of the corneal surface. Certain assumptions must be made about the shape of the cornea in order to use these principles. For the paraxial or central region of the cornea, a spherical surface is generally assumed. Keratometry uses this principle.

Although keratometry has been the mainstay of corneal measurement for over 140 years, another form of analysis, the placido disk or keratoscope, has been available for nearly the same time [110]. The main difference between keratometry and keratoscopy is that the first method is quantitative and the second is qualitative. In keratoscopy the reflected image of a placido disk on the

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cornea gives a qualitative assessment of distortion of the corneal surface. Its greatest value is in the evaluation of corneas with keratoconus or other surface irregularities. The initial targets were flat concentric rings that were viewed by the observer through a hole in the center of the target. Replacing the observer with a camera, Helmholz created the photokeratoscope [111]. To improve analysis of the photographic image by the photokeratoscope, Knoll modified the target by reconfiguring the rings to lie in different planes with the central rings furthest from the eye [112]. This modification helped to eliminate the curvature of field aberrations in the image and is especially important for quantitative analysis. Techniques to convert the photographic images of placido disks to curvature representations of the surface and the computer analysis of placido disk images improved the placido disk system even further [113-115].

Computerized systems using video capture technology led to the development of corneal topographers. Most corneal topographers use the placido disk in some form in order to analyze corneal shape. The algorithms used to reconstruct the corneal surface vary, depending on the device used [116-118]. Some devices use a look-up table based on spheres, while others use an arc-step method to reconstruct the corneal surface. There are many advantages of corneal topography over keratometry. It determines the curvature over a greater expanse of the cornea, covering up to 7-8 mm rather than the 3 mm zone measured by keratometry and it measures thousands of points rather than just four [119, 120]. In early topographers, diopter or radius of curvature values were displayed on a spoked map. Converting this numerical representation to color-

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coded maps based on contours of power or curvature, similar to contours of height on a land map, improved the clinical usefulness of topography [121].

The surface measured in topography extends far beyond the central cornea, so the assumption of sphericity used by keratometry fails. Corneal topography systems that use a pure spherical assumption tend to have large errors in the measurement of the peripheral cornea. The shape of the human cornea more closely approximates a prolate ellipsoidal model, steepest at the center or apex of the cornea and flattening through the periphery to the limbus [122-124]. Even though the actual corneal contour does not exactly match an ellipse, this approximation improves the accuracy of topographic measurements.

The TMS-2™ corneal topographer used in the studies contained within this dissertation is a placido disk system. It was first introduced in 1990 as the Corneal Modeling System [125]. The illuminated rings are arranged in a small cylinder, which is placed close to the eye. The reflected image is captured by a telecentric video camera and saved onto the computer using a video capture system. The distance to the eye from the camera is determined using a laser reflected off the corneal surface at a specific angle within the cylinder. The image then can be analyzed in terms of ring distances from the center and converted to curvature. The TMS system uses spheres as its basis for corneal surface reconstruction, with each sphere initially sharing a common central origin. This results in discontinuities in the surface since peripheral corneal areas are often less curved than central corneal areas in normal corneas. The opposite is true after most keratorefractive procedures. To form a single surface, the

spheres representing the various regions of the corneal surface are shifted along the videokeratographic axis until the surface is continuous. A complete description of this process and how the shifting of corneal regions accounts for the non-spherical nature of the cornea is given by Brenner [117].

The accuracy of corneal topography is important for the evaluation of corneal surface changes. Various studies have looked at the ability of the TMS-1™ and TMS-2™ systems to analyze spherical, astigmatic, radially aspheric and elliptical surfaces [126-130]. In general, the TMS system does well measuring the central two to three millimeters of these surfaces; however, there are increasing errors toward the surface periphery. Chapter 4 addresses how these errors affect the topographic indices and the reconstruction of the corneal surface from height and ring radius information.

Advances in measurement of the cornea using corneal topography have been rapid and seem to parallel the advances in refractive surgery. This symbiotic relationship stems from the need for greater and greater accuracy of corneal surface measurement to evaluate refractive surgery outcomes. Likewise, the increased accuracy of corneal topography has driven improvements in refractive surgery.

1.3 Correcting Ametropia

The optimal visual system is one in which the aberrations induced by the optical elements do not exceed the resolution limitations of the receptors and the analysis limitations of the visual cortex. Ideally, this relationship would be

maintained over the full range of visual requirements, from detection and recognition of distance and near objects to working in extreme light or dark conditions. The ideal visual system is emmetropic with excellent accommodation, reactive pupils, and quickly adapting photoreceptors. Of all these factors only refractive error and accommodation are routinely dealt with in the quest for excellent vision.

Spectacles continue to be the most optically and physiologically sound method of correcting ametropia when the only defect is a disconnect between the strength of the optical elements, the cornea and/or the lens, and the axial length of the eye. A large study showed that high contrast acuity for spectacle wearers is not significantly different from emmetropes. However, myopes in general have a slight decrease in contrast sensitivity at higher spatial frequencies as measured on the Vistech chart [131]. Since they are worn in front of the eyes, spectacle lenses serve as eye protection from minor injury, and if the lenses are plastic they provide some protection from ultraviolet light. In cases of decreased accommodation as in presbyopia, bifocal or progressive lenses allow clear vision at various distances. As vision changes with age, spectacle refractions are easily updated and the patient needs only to purchase new glasses to see well again.

Spectacles would seem to be the natural choice for refractive correction for almost everyone, but they have numerous drawbacks. They must be placed properly in front of the eyes, requiring a spectacle frame adjusted on the three points of contact on the head, the nose and two ears. They slide down the nose;

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put pressure on the temples or ears; scratch, smudge and steam up; and they require replacement as refractive error changes. A study of spectacle use among United States Army Armored Division soldiers revealed that dirty, smeared or poorly adjusted spectacles were frequent problems experienced on the job [132]. More than 54% of the subjects expressed a moderate to severe dislike of their spectacles. Their greatest difficulties arose when using night vision goggles or other vehicle mounted sights, when performing heavy physical activity or when they had to put on or work in a chemical protective mask. This report dealt with low to moderate refractive errors. High myopes suffer from spectacle minification, while high hyperopes suffer from a decreased field of view. High myopes also experience a greater reduction in contrast sensitivity when wearing spectacles versus contact lenses [133].

Contact lenses offer freedom from many of the problems of glasses, but carry many problems of their own. The Army study previously cited evaluated the feasibility of extended-wear contact lenses in the Armored Division. The most frequently reported problem among 45% of the subjects was contact lens insertion and handling problems. The ability to use night vision devices and scopes was greatly improved with contact lens use over spectacle use. Dusty environments presented the most significant problem for contact lens wearers.

As a replacement for spectacles, contact lenses were not ideal for everyone in the study as evidenced by the 23% who discontinued contact lens wear due to ocular complications. Outside of this specialized environment, the best vision obtained with soft contact lenses may be better or worse than that

obtainable with spectacles [134], although rigid contact lenses usually provide similar or superior vision to spectacles [135]. There are conflicting reports on the effect of contact lens wear on the contrast sensitivity function (CSF) [136-142]. Despite the many types of multifocal contact lenses available, this form of presbyopia correction is generally a compromise, whether the monovision or simultaneous vision modality is chosen [143-147]. The greatest disadvantage of contact lens wear is the physiological effect on the cornea because of decreased oxygen availability in the pre-corneal tear film [148-152]. This can lead to increased susceptibility to corneal infections and the increased possibility of vision loss [153]. Some patients suffer only mild discomfort due to dry eyes or allergies aggravated by contact lens wear. Others are so bothered they are unable to wear lenses at all, a condition known as "contact lens intolerance."

Both spectacle and contact lens wearers have the disadvantage of poor vision when uncorrected. Among high hyperopes and high myopes, this can be a serious disability and ranks high among the reasons for the search for alternatives. Even for moderate or low myopes there are numerous reasons to seek alternatives to spectacles or contact lenses. Certain occupations require minimum uncorrected visual acuities, such as police or fire fighters [154]. Some occupations have special equipment, which makes spectacle or contact lens wear difficult, such as laboratory technician or military aviator [155-157]. In many cases, patients choose refractive surgery because they simply want to be free from their dependence on glasses or the hassle of contact lens care.

1.4 Refractive Surgery

Currently there are many surgical alternatives to correct refractive error. These range from corneal to intraocular surgeries. As previously noted, refractive surgery currently is enjoying a surge in enthusiasm both among the practitioners offering the procedures and among the public seeking relief from glasses and contact lenses. Many more techniques are under investigation or in practice in various countries. The short term and long term results will be key in determining which procedures prove to be safe and efficacious.

Intraocular procedures include the intraocular lens (IOL), which is routinely implanted after cataract surgery. The IOL power can be calculated such that spherical refractive error existing prior to cataract surgery is corrected. Some surgeons augment this correction with an astigmatism correction using a corneal incisional technique such as astigmatism keratectomy (AK). The implantable contact lens (ICL) or phakic IOL is an intraocular lens placed either in the anterior chamber or in the space just anterior to the crystalline lens [158-160]. The process works by adding power to all the existing refractive elements of the eye. For both types of correction, extensive surgical skill and careful follow-up is required for success. The IOL implantation carries with it an increased risk of macular problems or retinal detachment, while the ICL has been associated with cataract development and pupillary block glaucoma [161].

Procedures that involve modification of the cornea are called keratorefractive procedures. These include RK, PRK, LASIK, intrastromal corneal implants, and epikeratophakia. Of the keratorefractive surgeries, the

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most common procedure is for the correction of myopia. In general, the goal of these surgeries is to reduce the refractive power of the cornea by increasing the radius of curvature of the central cornea. RK achieves this by reducing the strength of the peripheral cornea with radial incisions. As the peripheral cornea bulges out, the central cornea flattens (Figure 1). With PRK the excimer laser is used to subtract a plus lens from the anterior stroma of the cornea including Bowman's layer (Figure 2). LASIK also uses the excimer laser, but the plus lens is subtracted from the mid-stroma only after a corneal flap is created and the stromal bed is exposed (Figure 3). The intrastromal corneal ring reduces the power of the central cornea by adding thickness to the peripheral cornea (Figure 4). Both corneal inlays and epikeratophakia are based on the addition of minus power to the cornea.
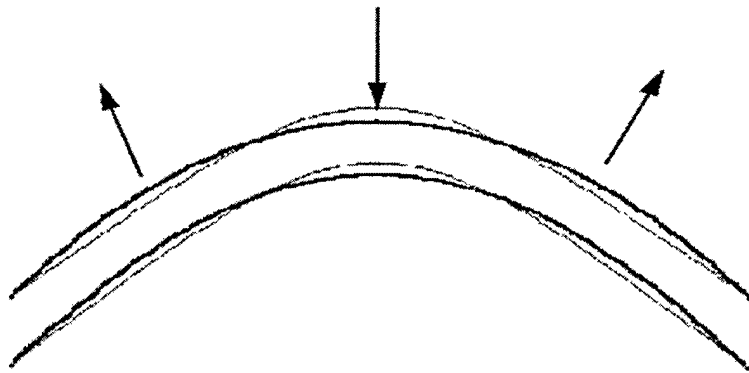
Figure 1: Corneal changes associated with radial keratotomy (RK). The thin lines depict the cornea prior to surgery. Once radial incisions are placed in the periphery of the cornea, the cornea weakens and displaces anterior and outward drawing the central cornea posteriorly (central arrow). The thick lines show the postsurgical corneal shape. Note that the curvature changes affect both the anterior and posterior corneal surfaces. The anterior cornea loses positive power and the posterior surface loses negative power, although substantially less than the anterior surface due to the lower index of refraction differential between the cornea and the aqueous humor.
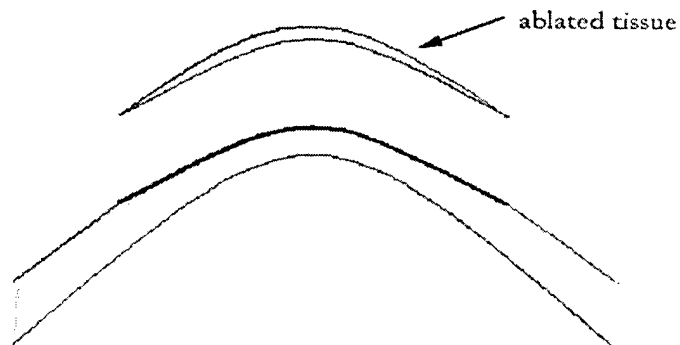
ablated tissue

Figure 2: Corneal changes associated with photorefractive keratectomy (PRK). The laser is used to ablate tissue from the anterior stroma. To reduce the positive power of the cornea, more tissue is removed centrally than toward the periphery. Most laser systems transition the ablation as it approaches the periphery to avoid abrupt surface changes. The posterior corneal curvature is generally unaffected by the procedure.

corneal flap

ablated tissue
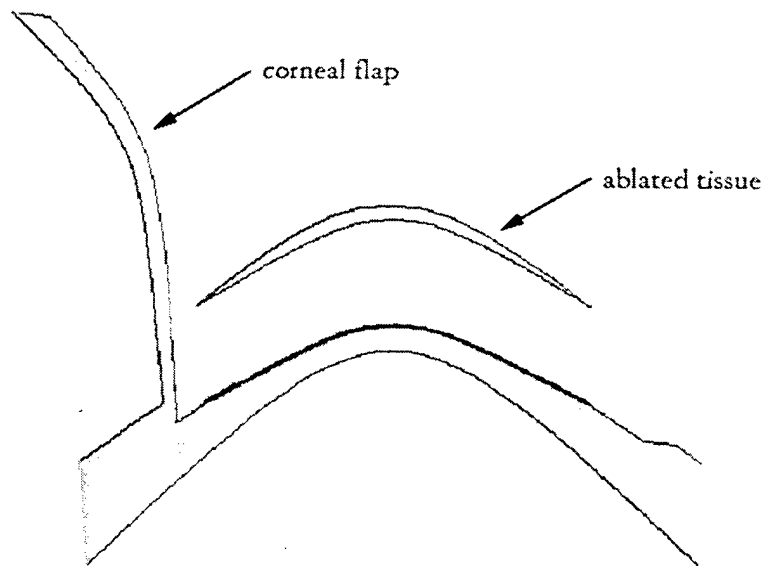
Figure 3: Laser in-situ keratomileusis (LASIK). A microkeratome is used to split stromal lamellar layers and create a corneal flap of approximately 160 microns thickness with a hinge. The excimer laser ablates the stromal bed to remove a positive "lenticule" as is done in PRK. The flap is then repositioned over the ablation zone.

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cross section of ring segments
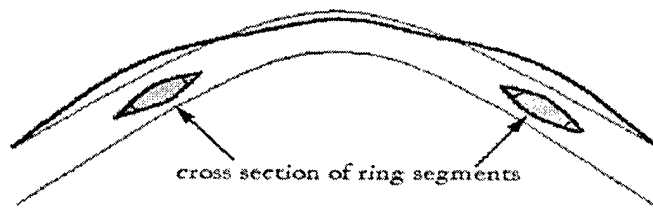
Figure 4: Mechanism of action of the intrastromal corneal ring segments (ICRS). Two arc segments are inserted into channels formed in the deeper stromal layers. Corneal tissues anterior to the segments are displaced forward, thereby "pulling" the central cornea flatter. The very central cornea tends to maintain positive eccentricity.

In this study, the primary emphasis is the evaluation of surface excimer procedures. PRK and astigmatic PRK (PARK) procedures have improved since their inception. In the first nine years, excimer lasers were only in use outside of the United States. Initially, ablation zones were only about 4-millimeters in diameter to reduce the amount of tissue removed from the corneal stroma, since rabbit studies had shown that shallower ablations produced less postoperative haze [162]. However, visual disturbances at night were very prevalent. Up to 60% of patients reported problems with haloes and glare [24, 80, 81]. Further studies showed that larger ablation zones were necessary to reduce symptoms at night [47, 163]. The initial lasers approved by the FDA, the Summit® Technologies laser and the VISX® laser had 6-millimeter ablation zones. Most patients in this study were treated using the Nidek® scanning slit laser that produces a 5.5-millimeter optical zone in an overall ablation diameter of 7-millimeters.

1.5 Outcomes Analysis

The success of a surgical procedure is measured in terms of its efficacy and safety. According to current Food and Drug Administration (FDA) guidelines, a refractive procedure is considered efficacious if the correction is within 1.00 diopter of the intended correction and the uncorrected visual acuity of the patient is 20/40 or better. Safety relates to maintaining visual capabilities such as best spectacle-corrected visual acuity (BSCVA). A loss of two lines or more of BSCVA from presurgical levels violates this standard. Any other vision-threatening complications such as infection, corneal opacification, cataracts or glaucoma also negatively impact the safety of a procedure. Safety is particularly important in elective procedures such as refractive surgery, as the eye is not diseased and according to the Hippocratic principle, doctors should "do no harm." Many studies, using the guidelines established by FDA, have looked at the efficacy and safety of refractive procedures as just outlined. Table 1 summarizes the results of some more recent studies of PRK, PARK, LASIK and the ICRS [164-172].

Table 1

Results of recent studies of Refractive Surgery Outcomes
Based on FDA Efficacy and Safety Standards

Study	Treatment	Ablation Zone (mm)	# Eyes	Attempted Correction (diopters)	F/up (mos)	≤20/40 UCVA (%)	±1.00 target (%)	≥2 lines loss of BSCVA (%)	Compli-cations (%)
FDA study 1995	Summit PRK	6.0	394	-1.50 to -7.00	12	95	89.4	1.2	NR
Schallhorn 1996	Summit PRK	6.0	30	-1.50 to -6.00	12	100	87	0	13[α]
FDA study	VISX PRK	6.0	480	-1.00 to -6.00	24	94	91	0.3	NR
McCarty 1996	VISX PRK	6.0	189	-5.00 to -10.00	12	71	65	8	4[θ]
Ohashi 1997	NIDEK PRK/PARK	5.0 to 6.0	47	-2.75 to -16.00	12	NR	72.5	0	NR
Deva 1998	NIDEK PRK/PARK	6.0 + 7.0 trans.	126	-1.00 to -16.00	6 to 36	78.5	≅ 80[β]	7	7[φ]
Muller 1998	VISX PARK	6.0 sph + 7x4.5 ell.	31	-1.75 to -10.50	6	77	62	10	NR
Kaskaloglu 1996	Technolas PARK	6.6	28	-1.00 to -14.25	6	55	78	7	NR
Helmy 1996	Summit LASIK	5.0	40	-6.00 to -10.00	12	75	85.7	5	0
Salchow 1998	Chiron LASIK	NR	66	-1.50 to -16.00	6	82.5	81	9.5	0
Schanzlin 1997	ICRS	7.0 inner diameter	99	-0.88 to -6.13	3	96	77	5	2[δ]
Summary	Across Proce-dures	5.0 to 7.0 mm	1404	-0.88 to -16.00	3 to 24	55 to 100%	62 to 91%	0 to 10%	0 to 13%

Notes: NR = not reported; α = 4/30 eyes were hyperopic in the Schallhorn study leading to a change in the ablation nomogram, no sight-threatening complications reported; θ = 7/189 eyes had transient increased intraocular pressure which normalized after discontinuing fluoromethalone, 1/189 eyes developed monocular diplopia; β = calculated value based on information in Deva study Results section; φ = complications included corneal haze, corneal infection and steroid induced secondary glaucoma (2 eyes); δ = ICRS complications included a small perforation of the anterior chamber of the cornea due to improper setting of the blade and a suspected infiltrative keratitis, both patients had the segments explanted.

More studies, including this dissertation, are now looking beyond these standards at the impact of refractive procedures on visual performance. The most common parameters measured have been glare disability and contrast sensitivity. As the measurement of visual performance beyond Snellen is one

emphasis of this dissertation, the results of studies that evaluated these aspects of vision will be presented in Chapter 2.

Results have been improving since the earliest procedures. For PRK central islands and haze were the most prevalent visual complication to overcome. With some laser systems, central islands developed due to obscured ablation pulses in the central zone or stromal changes in the postsurgical healing period. Other laser systems included means to avoid the development of central islands, which then left increased spherical aberration as the major change after refractive surgery. Both central islands and spherical aberration have been shown to relate to symptomatic visual changes [37, 39, 107, 173-176]. The surface quality of the stromal bed after ablation has been found to impact the development of haze [54, 177, 178]. Early lasers used a step-opening diaphragm that produced ridges in the stromal bed. Newer lasers are using ablatable masks, scanning slits and flying spot lasers to produce a smoother surface. Despite these improvements, most corneas develop some level of subepithelial haze during the first postoperative months with gradual resolution of clarity by six months.

LASIK and ICRS are two techniques that tend to spare the central cornea of haze. LASIK leaves the corneal epithelium and Bowman's layer intact by lifting a flap of anterior cornea and then ablating the underlying stroma. Stromal healing is less aggressive than epithelial healing, producing minimal haze. The ICRS procedure spares the central cornea by modifying the peripheral cornea to create the refractive effect in the central cornea. However, even with a clear

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central cornea these patients continue to have visual symptoms. Corneal shape changes may therefore be the overriding change responsible for visual changes. To determine how their corneal characteristics compare with the PRK and PARK patients, a small sample of LASIK and ICRS patients were also evaluated in this study.

The overall goal of this study was to evaluate the key factors of keratorefractive outcomes to determine which ones impact vision. The basis of this analysis involves measuring corneal clarity and shape as well as visual performance beyond Snellen. It is the maintenance or improvement of vision that drives interest in monitoring refractive surgery outcomes. Relieving people of the need for glasses or contact lenses while maintaining excellent visual performance has potential to improve the quality of life of individuals as well as increasing the applicant pool for certain professions. The U.S. military and many police forces exclude applicants who have had refractive surgery. The Federal Aviation Administration (FAA) currently is relaxing some of its restrictions, probably based on improvements in refractive surgery techniques and stability. The eventuality of refractive surgery acceptance may consist of visual performance and ocular integrity standards as opposed to blanket exclusion policies. Further studies to determine the battery of clinical tests that will adequately predict real world visual performance and long term ocular health will help to make this transition possible.

Chapter 1 References

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Chapter 2

Monitoring Refractive Surgery Outcomes Using the Small Letter Contrast Test

2.1 Introduction

2.1.1 The Problem

Refractive surgery patients generally have an excellent visual outcome when the outcome is measured in terms of high contrast visual acuity (HCVA). Some of these same patients experience visual disturbances under less-than-optimal conditions, however. The most frequent complaints are of vision problems in dim or artificial light or of glare and halos at night causing night driving problems [1-5]. These symptoms are not detectable with HCVA assessment, which is often normal shortly after surgery [1, 2, 6]. They are more likely associated with decreases in contrast sensitivity due to haze or corneal aberrations [7-10]. Refractive surgery techniques are rapidly improving, yet except for HCVA and refractive outcome, there remains very little agreement as to how to evaluate the functional success of a given procedure.

2.1.2 Contrast sensitivity

Measuring the contrast sensitivity function with sinusoidal gratings would provide a complete assessment of visual outcome in terms of spatial frequency, but it is time consuming and therefore impractical for clinical application. Charts with gratings, such as the CSV 1000, Functional Acuity Contrast Test (FACT) or VisTech

charts tests [11-13], allow assessment of contrast sensitivity at various spatial frequencies and are easier to administer than electronic-generated tests. There are drawbacks, however. Such tests require more explanation to the patient, since they introduce a new task that the patient may not be familiar with, and usually require a special lighting box or an external light source. Thus, an easier to administer, easier to interpret test that captures the essence of subtle visual changes after refractive surgery is needed.

Numerous studies have found that contrast sensitivity tests are sensitive measures of refractive surgery outcomes [14-17]. Letter charts that measure low contrast are advantageous over sine wave patterns in terms of simplicity and repeatability [18]. Clinical tests that use low contrast letters can be used to assess different aspects of the contrast sensitivity function (CSF) and are therefore useful for quickly determining specific performance levels. How well these tests provide results that correspond to performance on grating tests of contrast sensitivity is important if results are to be comparable. For foveal best-corrected vision, Herse and Bedell (1989) found that the contrast sensitivity for letter and grating targets of corresponding spatial frequencies is highly correlated [19].

The HCVA chart, whether of the Snellen, ETDRS (chart developed for the Early Treatment of Diabetic Retinopathy Study) or Bailey-Lovie configuration, is the most common visual test. The threshold of visual acuity corresponds to the high frequency region of the CSF. The Bailey-Lovie Low Contrast Chart tests vision at a single contrast level of 10% Michelson contrast with decreasing letter size from 0.8 to −0.5 logMAR (common logarithm of the minimum angle of resolution) at 6 meters

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testing distance (20/125 to 20/6.3 Snellen equivalent). Two charts measure the effect of contrast threshold for a specific letter size. The Pelli-Robson chart uses large 4.9 cm by 4.9 cm letters in groups of 3, each group decreasing by 0.15 log contrast level [20]. Measurements using the Pelli-Robson chart correspond to the peak of the CSF around 3 cycles per degree when a 3-meter test distance or closer is used. The Rabin Small Letter Contrast Test chart (SLCT) uses small 7.4 mm by 7.4 mm letters in lines of 10, each line decreasing by 0.1 log contrast level [21]. Figure 1 shows how using all four tests, the CSF can be approximated.
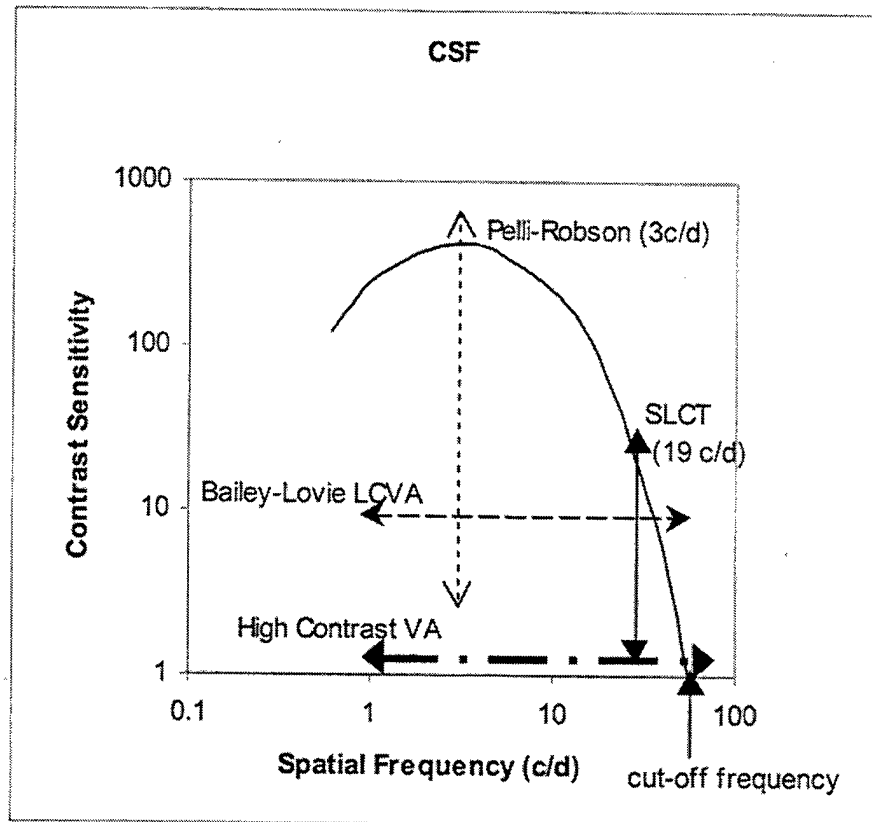
Figure 1 Four letter charts and the region of the contrast sensitivity function (CSF) that they test are indicated in this figure. The Pelli-Robson chart tests near the CSF peak of 3 cycles/degree. The Small Letter Contrast Test (SLCT) tests contrast sensitivity around 19 cycles/degree along the downward slope of the function. The Bailey-Lovey Low Contrast Visual Acuity chart (LCVA) tests at the 18% contrast level and High Contrast visual acuity tests at the highest contrast, measuring near the high frequency portion of the function.

The Pelli-Robson chart gives an assessment of the height of the CSF curve; the SLCT measures along the downward slope; the Bailey-Lovie shows the width of the curve; while the high contrast measurement pins the higher frequencies, often near the CSF cut-off. Although this may take less time than measuring the entire CSF with sinusoidal gratings, it is still too time-intensive for clinical applications.

2.1.3 Previous studies

Based on previous studies of contrast sensitivity after excimer laser refractive surgery, the portion of the CSF most often affected is in the mid spatial frequency range. This effect varies with the time course after the procedure and the type of procedure. Photorefractive Keratectomy (PRK) and astigmatic PRK (PARK) frequently result in more loss in the initial months following the procedure than is found after Laser in-Situ Keratomileusis (LASIK). Table 1 summarizes the results of some more recent studies of PRK, PARK, LASIK and the Intrastromal Corneal Ring Segments (ICRS) [2, 15, 17, 22-26].

One of the first studies to evaluate contrast sensitivity after PRK was completed by Verdon, et al (1996) at the Jules Stein Eye Institute. The ablation zone of the laser used in the study was only 5 millimeters in diameter since this study was completed prior to the final U.S. Food and Drug Administration (FDA) approval of the Summit laser. The currently approved lasers use a 6-millimeter ablation zone. By one year postoperative, the Pelli-Robson test, which measures the lower spatial frequencies in the CSF, had returned to normal. The Bailey-Lovie Low Contrast Acuity test showed a significant deficit in performance at the one-year point

(logMAR = 0.13 ± 0.09, t= 5.23, p=0.002). Presumably this is because the Bailey-Lovie test measures into the higher frequency portion of the CSF. Performance on the Bailey-Lovie high contrast letter chart was reduced by 0.05 ± 0.04 logMAR (1/2 line), which was also statistically significant (t=4.37, p=0.01). Putting these three results together, the CSF may appear to change as depicted in Figure 2.
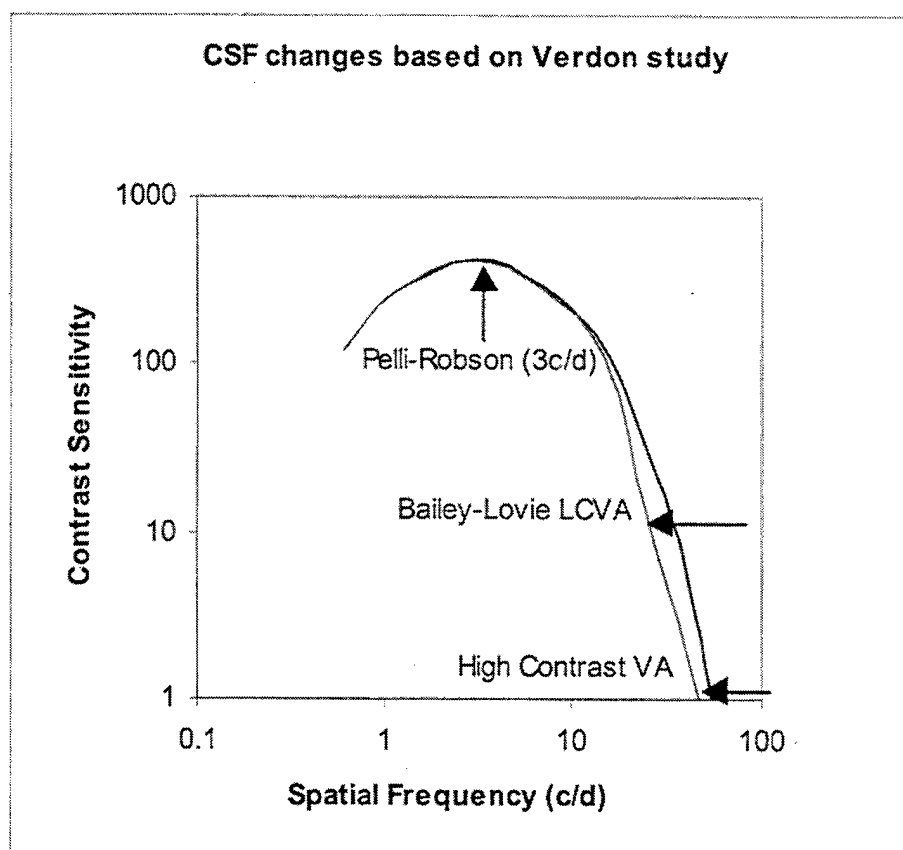
Figure 2 Graphical representation of the changes in visual performance after PRK measured by Verdon, et al (1996) as they might affect the CSF. The arrows indicate the three regions of the CSF evaluated in the study. There was no statistically significant change on the Pelli-Robson test results, while the Bailey-Lovie High and Low Contrast Visual Acuity charts both detected significant changes in performance 12 months after surgery. See text for details.

Table 1
Results of recent studies of Refractive Surgery outcomes using Contrast Sensitivity
(See notes below table)

Study	# Eyes	Range of Correction (diopters)	Contrast Test	1 month	3 months	6 months	12 months
Verdon Summit PRK (5mm zone) 1996	16	−5.08D (SD=±1.63)	Bailey-Lovie Low contrast chart (letters)	NR	NR	NR	Loss of 1 ½ lines (0.13 log CS)
			Pelli-Robson chart at 1 meter (letters)	NR	NR	NR	No Significant Reductions
Schallhorn Summit PRK 1996	30	-1.50 to -6.00	Stereo Optical Near Contrast Acuity (letters)	All contrast levels decreased	No Significant Reductions	No Significant Reductions	NR
Niesen MEL60 PRK 1997	46	-2.75 to -13.63	Vistech 6500 (gratings)	NR	Reductions at 12 & 18 c/deg	Reductions at 12 & 18 c/deg	No Significant Reductions
Ghaith Summit PRK 1998	30	-1.50 to -6.00	CSV1000 (gratings)	Reductions at 6,12, & 18 c/deg	Reductions at 6 & 18 c/deg	Reductions at 6,12, & 18 c/deg	NR
			MCT8000 (gratings)	Reductions at 1.5, 3, 6,12, & 18 c/deg	Reductions at 6 c/deg	Reductions at 6 c/deg	NR
			Pelli-Robson chart at 1 meter (letters)	Significant reduction in performance	No Significant Reductions	No Significant Reductions	NR
Wang Keracor PRK 1997	432	-1.25 to -6.00	F.A.C.T. 101 chart (gratings)	Reductions at 6 & 12 c/deg	Reductions at 6 & 12 c/deg	Reduction at 12 c/deg	No Significant Reductions
Wang Keracor LASIK 1997	137	-1.25 to -6.00	F.A.C.T. 101 chart (gratings)	Reductions at 6 & 12 c/deg	Reduction at 6 c/deg	No Significant Reductions	No Significant Reductions
Pérez-Santonja VISX 20/20 LASIK 1998	14	-6.00 -19.50	CSV1000 (gratings)	Reductions at 3 & 6 c/deg	No Significant Reductions	No Significant Reductions	NR
Carr Summit Apex LASIK 1998	94	-2.25 to -8.13	CSV1000 (gratings)	NR	Reductions at 3,6 & 12 c/deg	NR	NR
Schanzlin ICRS 1997	99	-0.88 to -6.13	Vistech (gratings)	NR	No Significant Reductions	NR	NR

Notes: *NR* (shaded blocks) = Not reported. The Bailey-Lovie and Pelli-Robson charts are described in the text. The Stereo Optical® Near Contrast Acuity test consists of 5 cards (contrasts 100%, 50%, 25%, 12.5%, and 6.25%) and logarithmically scaled letters. The CSV1000 chart tests contrast sensitivity at 3, 6, 12, and 18 cycles per degree. The Vistech, MCT8000 and F.A.C.T. 101 charts all test contrast sensitivity at 1.5, 3, 6, 12, and 18 cycles per degree.

Of the studies that measured performance at one month, all found a reduction in contrast sensitivity regardless of procedure or amount of correction. The PRK study by Niesen, et al evaluated patients before and after treatment and found a decrease in both the 12 and 18 cycles per degree spatial frequencies at 3 months after surgery, improving to preoperative levels by one year. Ghaith, et al also evaluated PRK and found a reduction across the CSF early on, but only the results of the CSV 1000 showed a persistent reduction in contrast sensitivity at 18 cycles per degree by 6 months after surgery. Wang, et al compared PRK to LASIK outcomes and found an earlier recovery after LASIK, with losses after PRK more towards the higher spatial frequencies tested. The study of contrast sensitivity after LASIK by Pérez-Santonja, et al showed a decrease in contrast sensitivity at 3 and 6 cycles per degree one month postoperatively which returned to preoperative levels or better by 3 months after surgery. Although a larger study by Carr, which used the same type of CS test and tested a similar population to Pérez-Santonja, showed a wider range of loss to include the 12 cycle per degree spatial frequency. Unlike the PRK studies there was no significant reduction found in the contrast sensitivity at 18 cycles per degree found in any of the LASIK studies.

2.1.4 Goal of this study

The purpose of this study was to evaluate the Rabin Small Letter Contrast Test for the assessment of visual performance changes after refractive surgery. The SLCT was developed in response to the need for a more sensitive measure of the visual capabilities of U.S. Army aviator candidates [27]. This group is generally

young, often emmetropic, with excellent HCVA. Low visibility and low luminance are two significant conditions that have been found to differentially affect individual pilot performance. How well an individual sees under these circumstances often determines his or her success as a pilot. Optical defocus and low luminance have also been shown to have a much greater impact on the SLCT than on HCVA measures [28, 29]. It is anticipated that the effect of changes in corneal optics and clarity after refractive surgery will likewise be more detectable with the SLCT than HCVA.

In this study, the SLCT was used to evaluate the visual performance of patients before and after surface excimer laser refractive surgery, both PRK and PARK. A few preliminary results are also presented for a small set of LASIK and Intrastromal Corneal Ring Segments (ICRS) implant patients. Refractive outcomes and HCVA were evaluated and related to the SLCT results. Since the primary complaint of patients is a reduction in vision at night, the SLCT was also used to assess small letter contrast sensitivity at low luminance.

2.2 Methods

2.2.1 Subjects

A total of thirty-seven patients (60 eyes) were enrolled in the study. Twenty-seven patients (42 eyes) had PRK or PARK as subjects in the FDA phase III trial for the NIDEK® EC-5000 Excimer Laser Corneal Surgery System (Gamagori, Aichi 443 Japan; Fremont, CA) which uses a scanning slit laser. Since the NIDEK protocol required a three-month waiting period between eyes, one of the PRK and one of the

PARK patients had their second eye procedure using the VISX® Star Laser (Santa Clara, CA) in order to reduce the time between eyes. Seven LASIK patients (12 eyes) and three ring patients (4 eyes) are included as examples of non-surface excimer procedures. Informed consent was obtained in accordance with the University of California Committee for Protection of Human Subjects and the FDA phase III trial procedures.

All procedures, except one, were completed at the University of California, San Francisco, Beckman Vision Center by the refractive surgeons designated in the FDA study. One of the LASIK patients (BY) had her surgery at another center, but was included in this paper since she had completed the preoperative evaluation of this eye at UCSF as part of the FDA study for PRK. One PARK patient was excluded from the study due to the development of a posterior subcapsular cataract secondary to corticosteroid use. Fifty-nine of the original sixty eyes enrolled were evaluated in this study. Table 2 outlines the patient demographics by treatment (Tmt).

Table 2
Patient Demographics

Tmt	Eyes n= 59	Age (sd)	M/F	Pre-op Spherical Equivalent (sd)	Pre-op cylinder (sd)	Low myope (<=-6D)	High myope (>-6D)	Pupil in mm photopic (sd)	Pupil in mm mesopic (sd)
PARK	24	47.6 (9.9)	37%M 63%F	-5.8 D (1.50)	1.5 D (0.878)	12 (50%)	12 (50%)	3.4 (0.7)	5.1 (0.9)
PRK	19	40.6 (10.2)	41%M 59% F	-7.5 D (2.09)	0.4 D (0.312)	4 (21%)	15 (79%)	3.7 (0.8)	5.3 (0.9)
LASIK	12	45.3 (5.5)	66% M 34% F	-7.8 D (1.34)	1.0 D (0.57)	3 (25%)	9 (75%)	3.5 (0.4)	5.2 (0.9)
ICRS	4	39.3 (13.1)	25% M 75% F	-3.1 D (0.22)	0.2 D (0.13)	4 (100%)	0 (0%)	3.0 (0.4)	4.9 (0.8)

2.2.2 Visual Assessment

At each visit, patients completed the testing required for the FDA study as well as the testing for this study. The tests included in this study consisted of a manifest refraction, photopic and mesopic pupil size, high contrast acuity using a projected Snellen chart, and low contrast acuity at two luminance levels using the SLCT. Additionally, tests that will be evaluated in a follow-on study to this one were completed. These included corneal topography using the Tomey TMS-2™ topographer and the objective measurement of haze using a prototype of the Nidek® Hazemeter.

The apparent entrance pupil size was measured using a digital video camera system mounted on keratometer stand. The patient was stabilized by the chin and headrest and fixated on a distant target. Pupil size was determined for both standard and low luminance lighting conditions. An infrared pass filter on an external lamp allowed video-capture of the pupil under low luminance conditions without stimulation of pupil constriction. The pupil image was captured when the patient's pupil was relatively stable in the ambient lighting conditions for both luminance levels. Still images from the video were imported into Adobe Photoshop® (version 4.0 for Macintosh) and entrance pupil size was determined from the enlarged image of the anterior segment of the eye. The pupil sizes for both luminance conditions are given in Table 2. Photopic pupil size is also obtainable from the TMS-2 topography map if the pupil margin is detectable in the image. Due to the higher light level used during video capture on the TMS-2, the lack of mesopic pupil size information and

the potential for inaccuracies from instrument accommodation, the TMS-2 pupil information was not used in the present study.

High contrast visual acuity was taken after manifest monocular refraction using an American Optical® projected Snellen chart with multiple 20/20 lines to reduce memorization. As much as possible, a single exam room with a mirror system to obtain the 20-foot testing distance was used. Visual acuity was recorded in logMAR with credit given for letters seen based on their relative value in their acuity line. This is different from the standard score per letter given on a logarithmic chart such as the Bailey-Lovie chart [30], since the Snellen projected chart is not logarithmic and has an unequal number of letters on each line. The best score possible on the Snellen projected chart is –0.30 logMAR, when all letters including the 20/10 line are seen. Letter values of all letters missed were added to the –0.30 logMAR baseline to determine visual acuity. Formula (1) shows how each letter value was calculated using 20/x as the line of interest and 20/x+1 as the next larger line on the chart.

$$\text{Letter Value} = (\text{logMAR}_{20/x \text{ line}} - \text{logMAR}_{20/x+1 \text{ line}})/\text{\# letters in 20/x line} \quad (1)$$

For example: The 20/15 line is –0.12 logMAR and the 20/20 line is 0.00 logMAR. The difference is 0.12 logMAR. Since there are 6 letters on the 20/15 line, each letter is worth 0.02 logMAR. Each of the 7 letters on the 20/10 line is worth 0.0257 logMAR. If the patient sees all the letters above and including the 20/20 line plus 3 letters on the 20/15 line, they will have missed a total of 10 letters. Their visual acuity is therefore –0.30 logMAR plus 7 times 0.0257 logMAR and 3 times 0.02 logMAR, or –0.06 logMAR.

Letter contrast sensitivity was measured using the Rabin SLCT at 3.3 meters instead of the recommended four-meter distance due to space constraints. The net result was an increase in the presented letter size to 20/32, which converts to a

spatial frequency of 18.75 cycles/degree using the formula: c/deg=30/MAR. The chart consists of 14 rows of 10 letters each with each row decreasing 0.1 log units in contrast from top to bottom. The SLCT was scored based on the number of letters correctly identified on the chart using a forced-choice procedure to determine threshold. Each correct letter is given a value of 0.01 log contrast sensitivity (logCS). The best score possible on the test is 1.30 log CS, the worst is –0.10 log CS. Subjects wore their manifest refraction in a trial frame and each eye was tested separately.

The chart was presented under two conditions. The room lights were set such that the chart luminance was 100 cd/m^2 for the standard luminance measurement, referred to as SLCT (L). The room lights were then lowered such that the chart was 3 cd/m^2 for the low luminance measurement, referred to as SLCT (D). Patients were allowed to adapt to the lower light level before measurements were made. When patients were unable to see any letters on the highest contrast line of the chart, logCS worse than –0.10, that SLCT exam score was excluded. In the present study this situation only occurred under low luminance conditions, SLCT(D). The impact of these exclusions will be addressed in the Discussion. Luminance levels were verified periodically using a Minolta® model LS-100 luminance meter. Measurements varied less than 2 cd/m^2 for the standard luminance condition and less than 0.5 cd/m^2 for the low luminance condition. Luminance levels were always verified when the use of a different exam room was necessary.

2.2.3 Data Analysis

PRK and PARK subjects were measured preoperatively (n=43) and postoperatively at 1 month (n=23), 3 months (n=43), 6 months (n=39), 9 months (n=26), 12 months (n=17), 18 months (n=5) and 24 months (n=2). All patients completed at least 6 months of follow-up. LASIK and ICRS patients were examined on the same schedule, but the follow-up time was much shorter due to the later start date of the LASIK FDA trials at UCSF and the limited availability of ICRS patients. Table 3 outlines the follow-up and control eye situation.

Table 3

Procedure	n (59)	Follow-up		Control Eye	
		Average	Range	Ipsilateral	Contralateral
PARK	24	9.4 mos	(6-17 mos)	16 (67%)	8 (33%)
PRK	19	11.0 mos	(6-24 mos)	12 (63%)	7 (37%)
LASIK	12	2.0 mos	(1-3 mos)	10 (83%)	2 (17%)
ICRS	4	6.0 mos	(3-9 mos)	1 (25%)	3 (75%)

Two issues needed to be addressed prior to data analysis. The first was whether preoperative data from the contralateral eye could be used as the control for the operative eye. This was considered since preoperative data was not available on all eyes. Specifically, at a patient's first exam in the present study he or she may already have had refractive surgery of one eye in the FDA study. Assuming both eyes are normal prior to surgery, visual performance of the contralateral eye should be sufficiently similar to allow its use as the control eye [31-33]. To verify this assumption in this study, an evaluation of the consistency of high contrast and small letter contrast performance was determined for patients where preoperative measures were available for both eyes. An assessment of the performance

difference between the two eyes versus their mean can be used to determine the sameness between the two eyes in this population [34]. When the data fall within two standard deviations of the mean of the differences then the two eyes can be considered equivalent. Figure 3 shows the plots of preoperative HCVA and SLCT performance plotted in this manner. For both tests, 96% of the differences (28 of 29 pairs of eyes) are within two standard deviations of the mean difference.
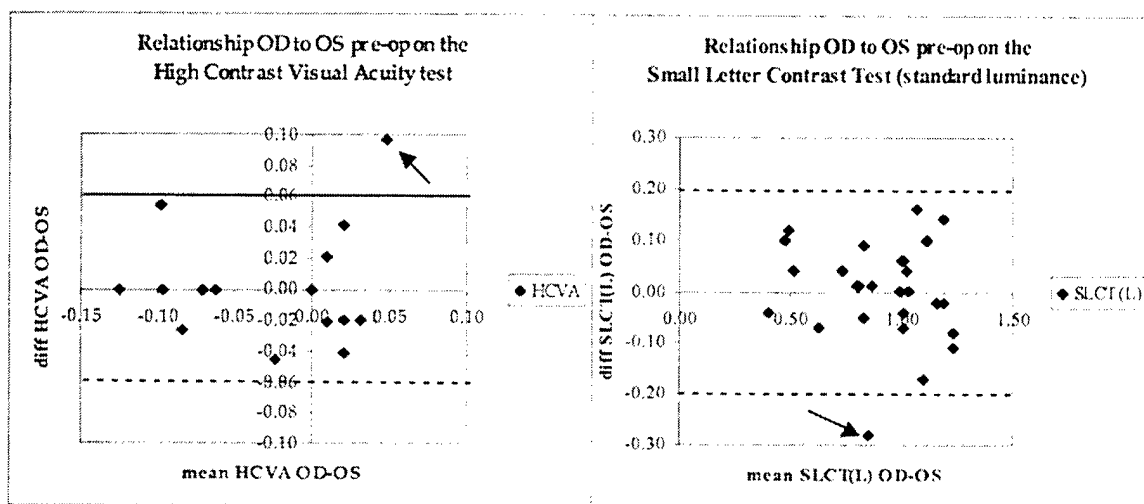
Figure 3 Verification of preoperative similarity between eyes for determination of value of contralateral eye information for use as control. The differences between right and left eye performance versus the mean performance for each pair of eyes is plotted for HCVA (left panel) and SLCT(L) (right panel). 28 of 29 pairs of eyes fall within 2 standard deviations (dotted lines) of the mean difference for both visual measurements. Arrows indicate the outliers.

The second issue was whether the two eyes of a single patient could contribute to the analysis independently after refractive surgery. To test this, the correlation r between the two eyes on the visual outcome measures had to be determined [35, 36]. This analysis could not be done until data collection was completed. The correlation of outcomes between eyes for HCVA and SLCT results six months after refractive surgery was $r = 0.75$ (HCVA) and $r = 0.39$ (SLCT). The

lower the correlation, the more distinct the impact of the procedure on each eye's performance. From this it can be seen that the correlation between eyes may impact the analysis of HCVA outcomes, while analysis of the performance measured by the SLCT is less tainted by interocular correlation.

Another effect that is often overlooked in studies of refractive surgery outcomes is spectacle magnification. In order to compare performance before and after surgery, Applegate recommended that the spectacle magnification effect should be taken into account [37, 38]. Of all the studies previously cited, the study by Verdon, et al is the only one to have considered this factor in their analysis, although it was only considered with respect to HCVA measurement [17]. For myopic corrections, shifting the correction from the spectacle to the corneal plane will lead to an improvement in vision just due to magnification of the image. Relative magnification is defined as the ratio of lens magnification at the corneal plane to lens magnification at the spectacle plane. The following simplified formula describes relative magnification:

$$RM = 1 - h_z F_s \tag{2}$$

where h_z is the difference between the corneal and spectacle plane, vertex distance, in meters and F_s is the back vertex power of the correction at the spectacle plane. The relative magnification can be up to 20% for a -10.00D myope if the vertex distance of the spectacles is 20 millimeters, a condition that is common for a trial frame. If, for instance, the spectacle visual acuity were 20/20 (0.00 logMAR) there would be almost a line improvement in visual acuity to 20/16.5 (-0.08 logMAR) just by moving the correction to the corneal plane, as is done in refractive surgery. All

preoperative visual performance measures were therefore adjusted by moving the refractive correction to the corneal plane and incorporating relative magnification. Postoperative measures were only adjusted if a significant refractive error of 2 diopters or more remained. Magnification is negligible otherwise. A 15-millimeter vertex distance was used to avoid over-emphasizing the magnification effect in the analysis, although Applegate found that the trial frame vertex distance is more commonly 17 to 24 millimeters.

High contrast visual acuity was adjusted based on relative magnification. The measured minimum angle of resolution (MAR) was divided by the amount of magnification to ascertain the MAR that would have been obtained had the correction been at the corneal plane:

$$MAR_{corneal\ plane} = MAR_{spectacle\ plane}/RM \qquad (3)$$

MAR is then converted back to logMAR for analysis.

Conversion of the SLCT is more complicated. The SLCT measures contrast sensitivity, not acuity, a factor that cannot easily be converted by simple magnification. However its relationship to the CSF and known properties of the CSF does make conversion possible. To determine the appropriate conversion, the effect of magnification or minification on SLCT performance had to be tested. By adjusting the distance to the test, the details of the presented letters will subtend a different angular extent, measured in minutes of arc (MA). MA is converted to cycles per degree to determine the actual spatial frequency of the test condition:

$$Spatial\ Frequency\ (in\ cycles\ per\ degree) = 30/MA \qquad (4)$$

Figure 4 shows the performance of three normal subjects on the SLCT at various viewing distances. There is a rapid fall off in performance as higher spatial frequencies (longer viewing distances) are tested. It can be seen from the graph that a slight shift in spatial frequency results in a larger shift in log contrast sensitivity. All three subjects had the same slope in this region: -0.05 logCS/(c/deg). The effect of minification preoperatively can therefore be quite significant to performance on the SLCT. One cycle per degree change can lead to a loss of five letters, or 0.05 logCS, on the SLCT. The shift on the horizontal axis of the three subjects appears to be due to their high contrast visual acuity. This can be derived from the fact that the slope of each subject's plot points toward their high contrast acuity on the spatial frequency axis where logCS is zero (100% contrast level).
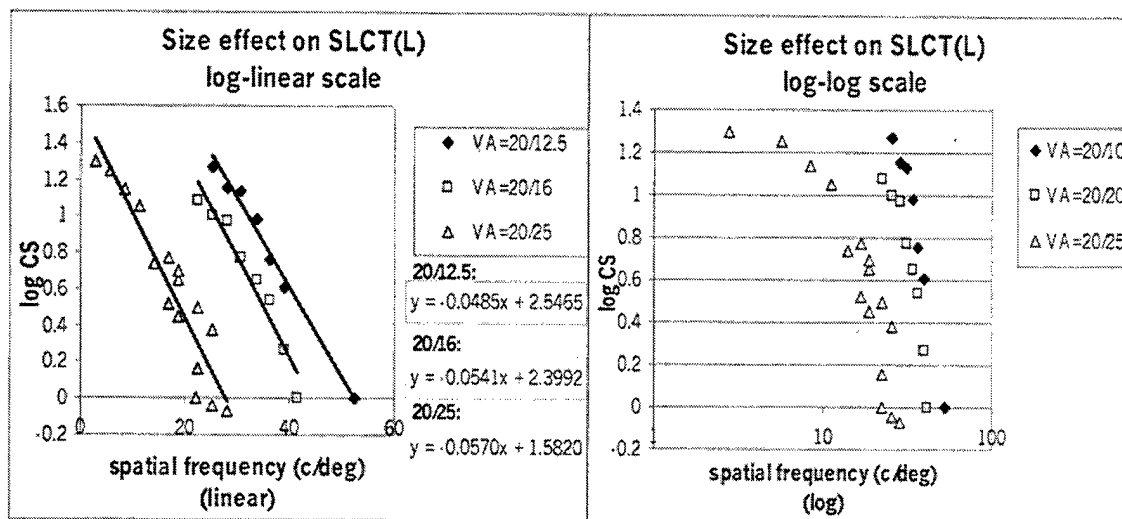
Figure 4 Three subjects with different baseline high contrast visual acuities were tested on the SLCT(L) test using the distance to the test to change the spatial frequency of the low contrast letters. Plotted on a log-linear scale (left panel) the 3 slopes are parallel despite different visual acuity levels and are easily interpreted to determine the effect of changing spatial frequency on contrast sensitivity. The regression equations are also provided. Plotted on a log-log scale (right panel), the shape of the CSF can be seen in the subject with 20/25 visual acuity. The other two subjects are anticipated to have a higher overall function.

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Based on these results, the procedure described as follows was employed to convert preoperative SLCT scores. Relative magnification was applied to the angular size of the letter details on the SLCT (1.6 minutes of arc at 3.33 meters test distance) to determine the adjusted MA for each exam. Adjusted MA was converted to adjusted spatial frequency using formula (4). Preoperatively, the relative magnification caused a minification of the image, a reduction in the presented MA and an increase in spatial frequency of the testing condition. The subject's preoperative logCS score on the SLCT was therefore reduced by effectively testing at a higher spatial frequency. The logCS score was adjusted for this reduction by applying the empirically-determined slope to determine the change in logCS:

$$\Delta logCS = (-0.05)^*(SF_{std} - SF_{adj}) \tag{5}$$

where SF_{std} is the spatial frequency of the standard test condition without minification and SF_{adj} is the spatial frequency adjusted for the actual measurement condition. The logCS, which takes into account the relative magnification factor, is therefore:

$$logCS_{corneal\ plane} = logCS_{spectacle\ plane} + \Delta logCS \tag{6}$$

Once the preoperative measures were adjusted for relative magnification, the impact of refractive surgery on performance was determined. First the outcomes were assessed with respect to the FDA guidelines. Then visual performance for HCVA, SLCT(L) and SLCT(D) was evaluated longitudinally by comparing mean performance levels at each exam period with the mean preoperative level. Significant changes were determined using the paired t test. Stability was then identified as the time frame when changes in performance levels at subsequent

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examinations were no longer statistically significant. Based on this stability point, the change in performance was again assessed using the latest post-stability exam paired with the preoperative exam. The mean follow-up for each refractive surgery modality is listed in Table 3. Finally, multivariate regression was applied to the outcomes of the two surface refractive procedures evaluated in this study to establish the effect of subject variables and amount of correction on visual outcomes.

2.3 Results

2.3.1 Refractive outcome

According to FDA guidelines [39], the efficacy of a refractive procedure is measured in terms of achieving the target correction (±1.00D), an uncorrected visual acuity of 20/40 (0.3 logMAR) or better and a stable refraction. The FDA safety guidelines aim for less than 5% of subjects with a loss of two or more lines (approximately 0.2 logMAR) of best spectacle corrected visual acuity (BSCVA) and less than 1% of subjects with either haze beyond 6 months, BSCVA worse than 20/40 or an adverse event.

Based on the FDA standards, the results for the surface laser (PRK and PARK) patients in this study were excellent. As shown in Figure 5, eighty-five percent of patients were within ±1.00D of target correction. All patients, except one PRK and one PARK patient had 20/40 or better uncorrected visual acuity. These two patients were the same patients noted in the "undercorrected" section of Figure 5. The PRK patient (PM) developed haze and regression of refractive effect due to an

atypical healing response during the early postoperative period. The PARK patient (JN) had a −0.50D residual refractive error six months after the procedure and has experienced a late refractive regression of an additional 1 diopter of myopia at nine months in one eye only. Two LASIK patients were undercorrected by more than 1.00 diopter with respect to the target correction of −0.50D, while two of the ICRS patients (50%) were undercorrected by more than 1.00 diopter from target. One of the LASIK patients opted for retreatment and one of the ICRS patients opted for removal of the ring segments due to undercorrection.
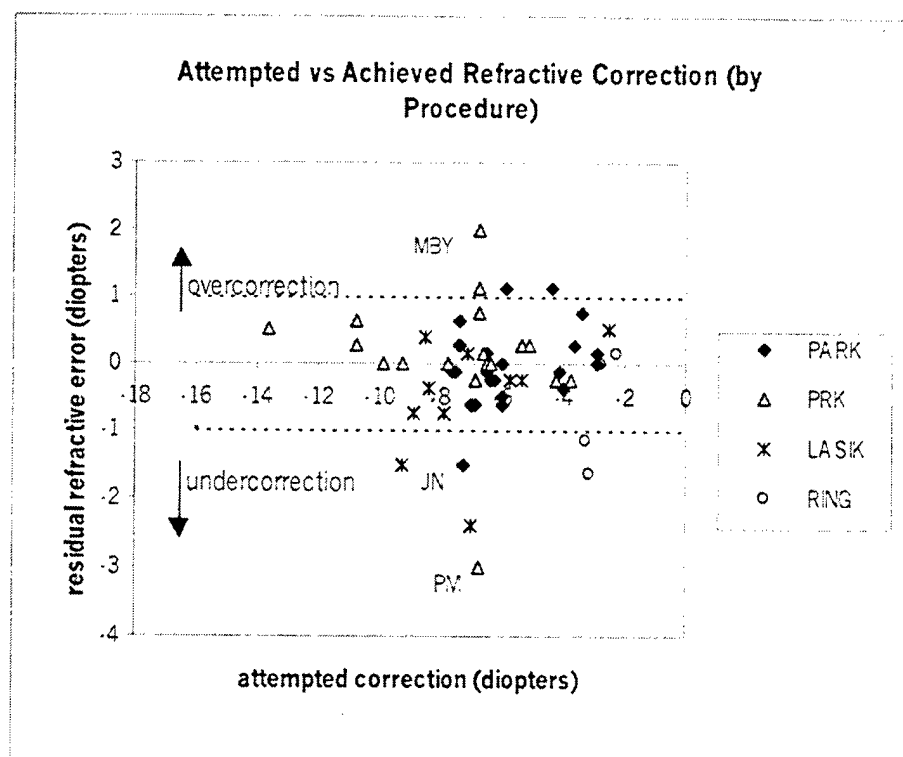
Figure 5 The difference between the attempted and achieved refractive correction is the residual refractive error. This difference, in diopters, is plotted against the attempted correction. 4 patients (2 PRK and 2 PARK) were overcorrected, 3 of these had a residual refractive error of 1.125D spherical equivalent. 2 patients (1 PRK and 1 PARK) were undercorrected. Eighty-five percent of the combined PRK/PARK group was within 1.00D of attempted correction. The LASIK and ICRS results are included for informational purposes only as their results are too early to assume stability of endpoint or accuracy of correction nomograms.

2.3.2 Longitudinal outcomes and stability

Figure 6 is an overview of the results of the Small Letter Contrast Test measurements under both the standard light condition of 100 cd/m^2 [SLCT(L)] and the low luminance condition of 3 cd/m^2 [SLCT(D)]. Only the PRK and PARK subject results are plotted on this figure. The HCVA results are plotted with the SLCT results to show the relative magnitude of the slight decrease of HCVA at one month with partial recovery and stability by month 3. The initial loss of HCVA from preoperative levels to one month was statistically significant (change in logMAR = 0.053 ± 0.08, t=-3.1, p=0.005). Given a mean preoperative visual acuity of −0.1249 logMAR (20/15), after adjustment for spectacle minification, the mean HCVA at one month is −0.0719 logMAR (20/19) or almost a line of acuity change. HCVA performance improves slightly by the 3 month examination, however the reduction in performance from baseline is still statistically significant (change in logMAR = 0.034 ± 0.07, t=-3.3, p=0.001). This equates to approximately a half line of visual acuity loss. After 3 months HCVA performance stabilizes and the decrease from baseline is statistically significant at all subsequent examinations.

Performance under both SLCT conditions decreased significantly in the first month, consistent with other studies of low contrast or contrast sensitivity changes during the healing phase after surface excimer procedures. The mean loss at one month for the SLCT(L) was more than 3 lines (logCS = -0.33 ± 0.28, t=5.5, p<0.001) and for the SLCT(D) was almost 3 lines (logCS = -0.28 ± 0.19, t=6.7, p<0.001). The graph shows that both measures then slowly improve by 3 to 6 months with the average values remaining below the initial levels. The slight improvement of 0.05 ±

0.29 logCS on the SLCT(L) from the first to the third postoperative month is not statistically significant (p=0.50), however SLCT(D) performance does show a more significant change in the same time period (logCS = 0.14 ± 0.20, t= 2.5, p=0.01). After 3 months there appears to be very little change in performance and none of the changes are statistically significant.
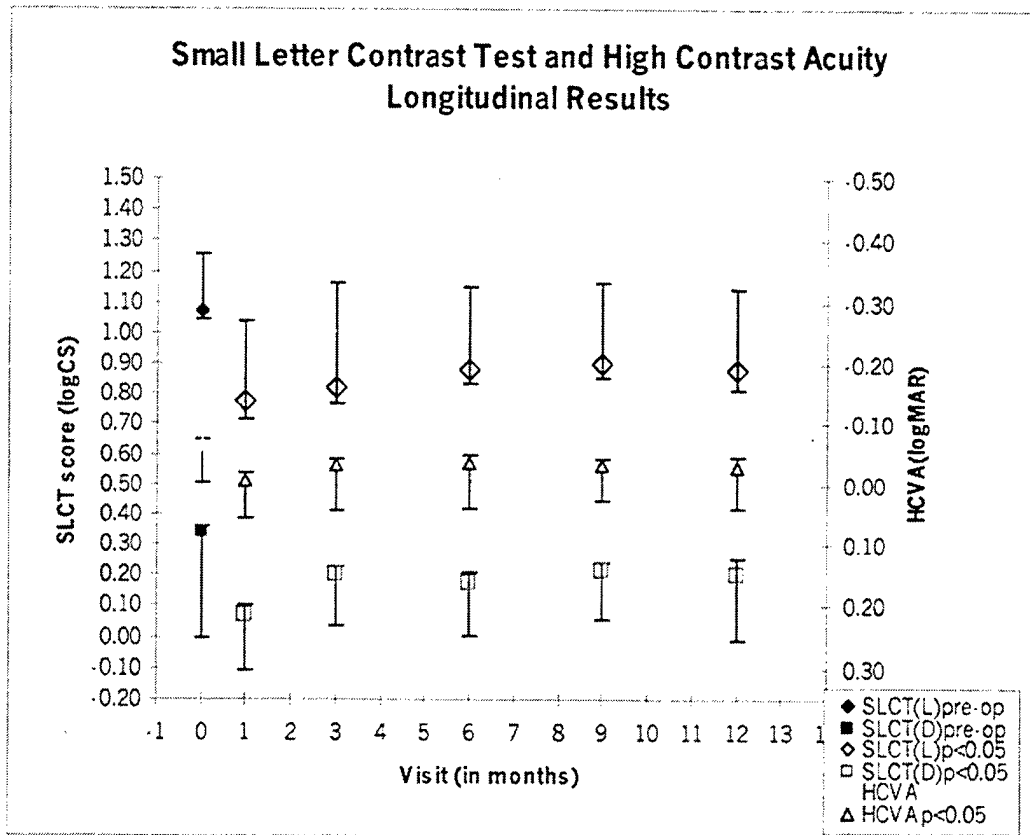
Figure 6 The mean measurements and standard deviations of all three performance measures are plotted against time since surgery. For both the SLCT (y-axis on left) and the HCVA (y-axis on right) an upward shift on the axis indicates an improvement and each interval equals one line of performance gain or loss. The error bars are standard deviation (longer half-bar) and standard error (shorter half-bar). All three measures decline at the first month visit with only HCVA returning to near pre-op levels by month 3. SLCT(L) and SLCT(D) are stable after 6 months.

2.3.3 High contrast visual acuity (HCVA)

In Figure 7 the change in HCVA from before to after surgery is plotted. The mean loss in HCVA for the entire group was statistically significant. There also appears from the figure to be a slight trend towards greater loss with better initial visual acuity, as would be expected from the independence of pre- and postoperative performance. Only one patient, the same PRK patient (PM) noted previously to have had regression and poor uncorrected visual acuity, lost two lines of BSCVA. He lost 0.2478 logMAR from an initial acuity of –0.187 logMAR (20/15+2) to a postoperative visual acuity of 0.061 logMAR (20/25+2). As a group, there was a mean loss after PRK of 0.053 ± 0.09 logMAR which was statistically significant (p=0.03) and a mean loss of 0.009 ± 0.07 logMAR after PARK which was not significant (p=0.52). For both surface excimer groups there are patients who show improvement as well as decrement in HCVA. The LASIK and ICRS patients generally show a reduction in HCVA, although the results for these patients have not been verified for stability. Table 4 details the changes in HCVA by procedure and by the level of myopic correction.

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HCVA pre vs change in post op performance
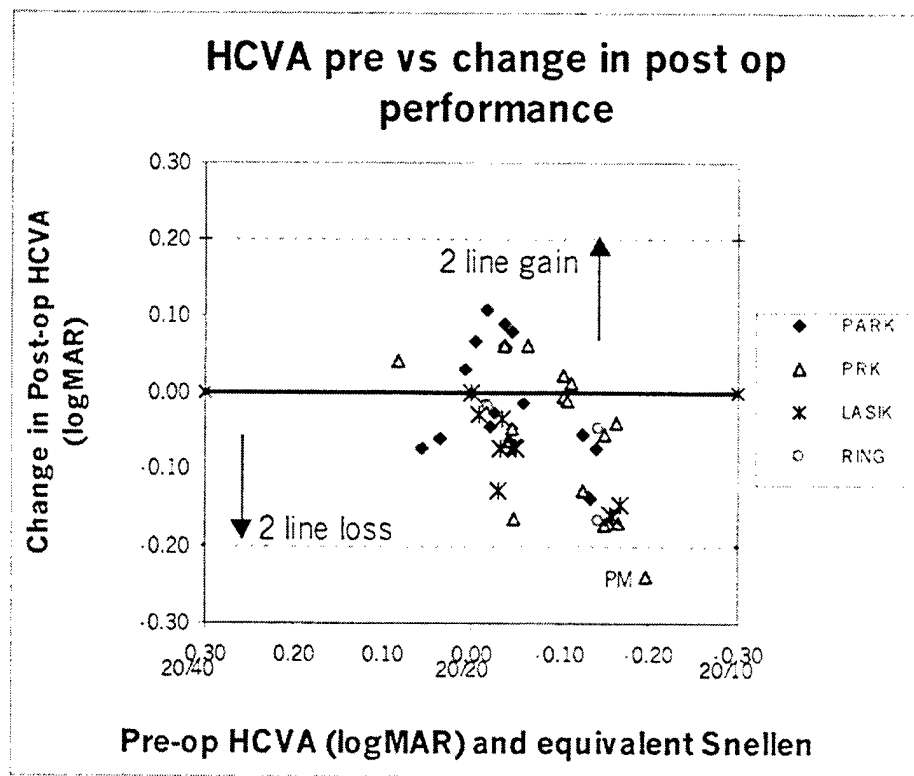
Figure 7 Postoperative visual acuity change (logMAR) is compared to preoperative visual acuity. Negative values indicate better acuity on the x-axis. Snellen equivalents are provided for comparison. Positive values indicate an improvement in HCVA on the y-axis. Only one patient lost two lines of best spectacle corrected visual acuity (BSCVA) due to corneal haze (PM). His measured loss was from –0.19 log MAR, 20/15+2 prior to surgery to 0.04139 logMAR, 20/25+2 after surgery.

Table 4
High Contrast Visual Acuity after Stability
Data in Figure 7

Procedure	n	Change in HCVA (logMAR)	s.d.	s.e.	t	p=
PRK/PARK (total)	43	-0.029	0.08	0.012	-2.3	0.03
PRK	19	-0.053	0.09	0.021	-2.6	0.02
PARK	24	-0.009	0.07	0.014	-0.7	0.52
High correction (>-6.00D)	27	-0.038	0.09	0.017	-2.2	0.03
Low correction (<=-6.00D)	16	-0.013	0.07	0.018	-0.8	0.45
LASIK (=>1 mo)	12	-0.088	0.06	0.017	-5.3	0.006
ICRS	4	-0.050	0.05	0.025	-1.7	0.17

2.3.4 Small Letter Contrast Test (standard luminance)

In order to evaluate whether there is a change in SLCT performance after surgery in Figure 8 each individual's change in performance is plotted against his or her preoperative performance. All the PRK and PARK patients are 6 months or more postoperative, having reached a relatively stable performance level. The LASIK and ICRS patients are included for comparison even though they are less than 6 months postoperative. The results show a split between the performance levels of the PARK and PRK subjects. Some of the PARK patients appear to have improved while the majority of PRK patients now fall below the line indicating a decrement in performance. The amount and significance of changes in SLCT(L) after reaching stability is detailed in Table 5.
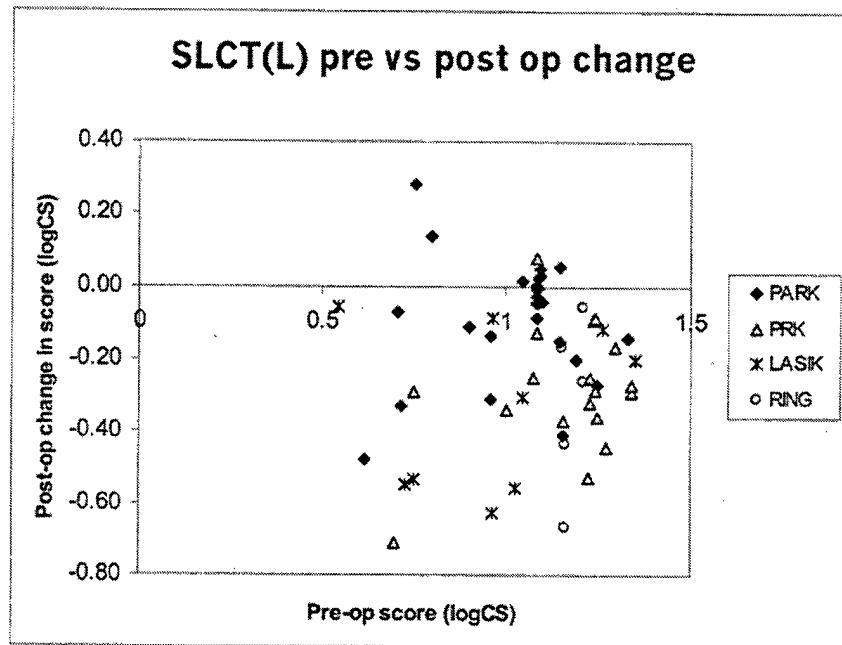
Figure 8 Postoperative performance on the SLCT(L) is plotted against preoperative performance. Points that fall below the line indicate a decrement in performance, whereas points above the line are improvements. The general trend is toward a decrease in performance postoperatively with only a few subjects realizing an improvement, primarily PARK subjects and one PRK subject. All LASIK and Intrastromal Corneal Ring Segment (RING) patients experienced a decrement. See also Table 5.

Table 5

Small Letter Contrast Test (standard luminance = 100cd/m^2)
Data in Figure 8
photopic pupil size

Procedure	n	Change in SLCT(L)	s.d.	s.e.	t	p=
PRK/PARK	43	-0.18	0.20	0.031	-5.8	<0.001
PRK	19	-0.27	0.18	0.041	-6.3	<0.001
PARK	24	-0.11	0.19	0.039	-2.8	0.009
High correction (>-6.00D)	27	-0.24	0.19	0.037	-6.6	<0.001
Low correction (<=-6.00D)	16	-0.08	0.19	0.048	-1.7	0.106
Small Pupil (<3.5mm)	21	-0.13	0.21	0.046	-2.9	0.009
Large Pupil (>=3.5mm)	22	-0.22	0.19	0.041	-5.7	<0.001
Age Group 1 (<45 years)	23	-0.16	0.16	0.033	-4.8	<0.001
Age Group 2 (>=45 years)	20	-0.20	0.24	0.054	-3.7	0.001
LASIK	12	-0.30	0.24	0.069	-4.3	0.01
ICRS	4	-0.32	0.24	0.120	-3.0	0.04

Because the two groups differ in the amount of refractive correction, separate comparisons based on high or low myopic corrections are presented. Having had PRK or a higher refractive correction is significant in terms of a greater reduction in SLCT(L) performance than having PARK. Eyes that had a low refractive correction did not experience a significant change in SLCT(L). Age and pupil size are also potential factors in performance on low contrast tasks, so these factors are presented as well. All variables examined were significantly correlated to a decrease in SLCT(L) performance. There was no statistically significant difference between these groups when stratified by age (p=0.14) or pupil size (p=0.48) in terms of their relationship to performance on the SLCT(L), however. Multivariate regression using

age, pupil size and magnitude of refractive correction (measured in terms of spherical equivalent) shows that the most significant variable for the prediction of a change in SLCT(L) is the amount of correction ($r=0.518$, $F=15.068$, $p<0.001$). LASIK and ICRS patients all showed a decrease in performance postoperatively.

2.3.5 Small Letter Contrast Test (low luminance)

The changes in performance on the Small Letter Contrast Test under low luminance conditions are plotted in Figure 9. For this test some of the PARK patients showed an improvement in performance and most of the PRK patients' performance shows a decrement. The pre- and postoperative scores of eyes that were not measurable under low luminance conditions were eliminated. The impact of this is covered in the Discussion and can be seen in the lower number of eyes analyzed in Table 6. The number of eyes eliminated is indicated in the table as "(less x)."

Table 6 details the changes in SLCT(D) by procedure and amount of correction after patients' visual performance has reached stability. Significant factors in terms of performance on the SLCT(D) include having had PRK, a higher correction, a larger pupil size under mesopic conditions or age greater than 45 years. Multivariate regression using the factors which have significant t-test values shows that the most significant variable for the prediction of a change in SLCT(D) is the amount of correction ($r=0.296$, $F=3.942$, $p=0.054$). LASIK patients show losses similar to PRK patients. The small group of ICRS patients had a mean loss of SLCT(D) greater than any other group.

SLCT(D) pre vs post op change
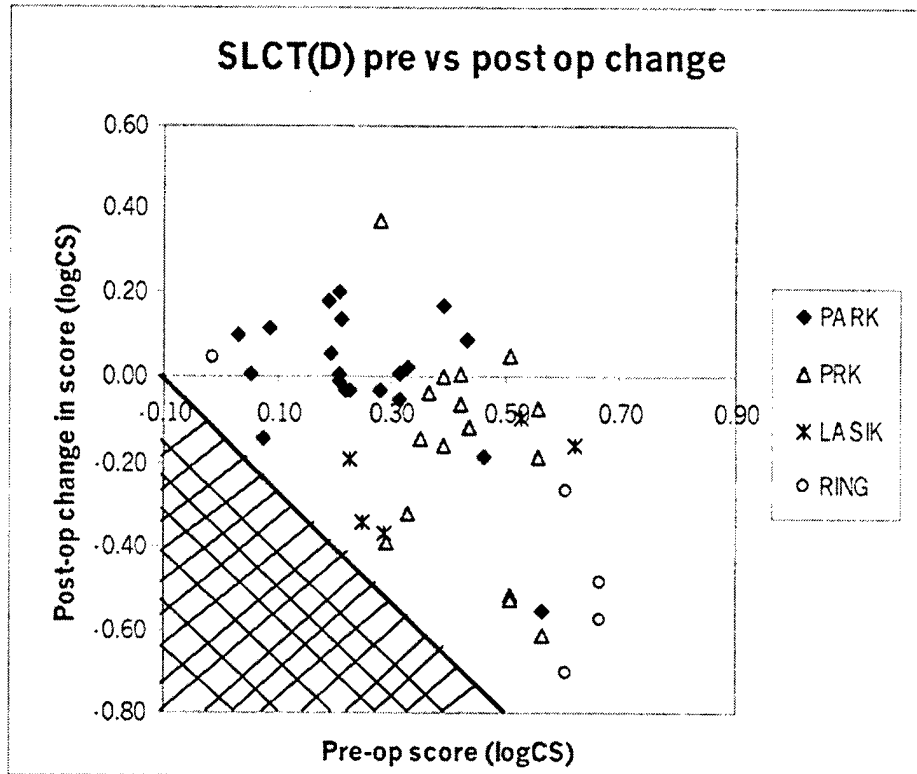
Figure 9 Postoperative SLCT(D) scores plotted against preoperative scores. Most PARK patients appear to improve post-operatively, however the mean change is not significant. More PRK patients experienced a decrement than an improvement in performance. All LASIK and all but one RING patient had a decrease in performance. See also Table 6. The shaded area represents the effect of bias in this test. Depending on the subject's preoperative performance, loss of contrast sensitivity under low luminance postoperatively could not be measured into the shaded zone. See Discussion.

Table 6

Small Letter Contrast Test (low luminance = 3cd/m^2)
Data in Figure 9
Mesopic pupil size

Procedure	n	Change in SLCT(D)	s.d.	s.e.	t	p=
PRK/PARK (less 5)	38	-0.10	0.22	0.036	-3.0	0.004
PRK (less 2)	17	-0.19	0.24	0.058	-3.5	0.003
PARK (less 3)	21	-0.03	0.17	0.037	-0.9	0.38
High correction (>-6.00D) (less 3)	24	-0.15	0.24	0.049	-3.2	0.003
Low correction (<=-6.00D) (less 2)	14	-0.02	0.14	0.037	-0.6	0.59
Small Pupil (<5.5 mm) (less 3)	20	-0.09	0.21	0.047	-1.8	0.09
Large Pupil (>=5.5 mm) (less 2)	18	-0.12	0.22	0.052	-2.4	0.03
Age Group 1 (<45 years) (less 1)	22	-0.07	0.18	0.038	-1.8	0.08
Age Group 2 (>=45 years) (less 4)	16	-0.15	0.24	0.060	-2.5	0.02
LASIK (less 4)	8	-0.27	0.12	0.042	-7.4	0.002
ICRS	4	-0.45	0.36	0.18	-2.8	0.05

2.4 Discussion

2.4.1 Monitoring change

Monitoring subtle changes in visual performance after any type of refractive surgery is important, both for evaluation of individual recovery as well as for evaluation of refractive techniques. The relative impact of corneal aberrations or mild media haze is much greater on measures of contrast sensitivity than of high contrast acuity. This has been shown in numerous studies of visual performance in corneal

edema, corneal distortions, refractive surgery and early cataract [22, 40-43]. In this study, the early loss of HCVA at one month was likewise less statistically significant than the decrease under both the standard and low luminance measures of SLCT performance (Figure 6).

HCVA stabilizes by three months after surgery. Performance on the SLCT shows continued improvement up until the sixth month, slowing or stabilizing thereafter. After six months, the SLCT at standard luminance continues to detect more of a deficit in performance than the SLCT at low luminance or the high contrast acuity test. As was displayed in Tables 5 and 6, the type or amount of refractive correction, pupil size and age show a relation to this change. Using regression, the amount of correction is the strongest determinant of SLCT change under both luminance conditions.

2.4.2 The effect of sampling: SLCT versus HCVA

From Tables 4 and 5 it would appear that the SLCT measures a greater deficit in performance than HCVA. The level of statistical significance of the change in performance is likewise greater for SLCT than HCVA. The difference may be due to the sampling advantage of the SLCT over HCVA tests owing to the difference in number of presentations and the differing regions of the CSF tested by each modality [44]. The SLCT measures along the y-axis of contrast sensitivity at a single spatial frequency, while the HCVA measures along the x-axis of threshold spatial frequency at a single contrast level. Using the slope determined in Section 2.2.3, for

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each cycle per degree decrease in HCVA the expected decrease in SLCT performance is 0.05 logCS.

Generally the range of visual acuities obtained pre- and postoperatively in this study was between 20/15 and 20/20. In this range, a line of HCVA change is equivalent to a 10 cycle per degree spatial frequency shift along the x-axis of the CSF. The change in SLCT for one line of HCVA at this level would be 0.05 logCS/(c/deg) x 10 c/deg = 0.5 logCS, or 5 lines of performance on the SLCT. Five lines on the SLCT is 50 letters, while from 20/15 to 20/20 on the HCVA is six letters. The ratio of the two tests in terms of letters is therefore 8.3:1. From this ratio it can be seen that the SLCT may be more suitable for the detection of fine, incremental visual performance changes due to the greater number of letters corresponding to a loss of only one line of HCVA.

Table 7 takes the HCVA outcomes as given in Table 4 and using the 8.3:1 ratio shows the expected change in performance on the SLCT along with the measured change in SLCT performance as given in Table 5. The ratio of expected to measured SLCT(L) shows that the 8.3:1 letter ratio overestimates the change for all cases except PARK. This may be due to a greater slope of the postoperative CSF in this region than predicted by the slope of 0.05 logCS/(c/deg) or that the letter ratio is less than predicted based on the 20/15 to 20/20 HCVA shift. However, this analysis does show that the magnitude of HCVA and SLCT changes are related based on the slope of the CSF and that the difference in magnitude of the two measures is a function of region of the CSF that each test measures.

Table 7
Prediction of change in SLCT(L) performance based on change in HCVA

Procedure	HCVA change (logMAR)	Expected SLCT(L) change	Measured SLCT(L) change	Ratio of expected to measured
PRK/PARK (total)	-0.029	-0.24	-0.18	1.33
PRK	-0.053	-0.44	-0.27	1.62
PARK	-0.009	-0.07	-0.11	0.64
High correction (>-6.00D)	-0.038	-0.30	-0.24	1.25
Low correction (<=-6.00D)	-0.013	-0.11	-0.08	1.38
LASIK (=>1 mo)	-0.088	-0.73	-0.30	2.43
ICRS	-0.050	-0.41	-0.32	1.28

2.4.3 Spectacle magnification

In order to compare post and preoperative results at the same refractive plane, the effect of image minification due to myopic spectacle correction prior to surgery is significant. The adjustment results in a higher performance level prior to surgery than obtainable with spectacles and a more pronounced change after surgery. When the data in this study are analyzed without adjustment, there is no statistically significant change in HCVA or SLCT(D) after stability has been reached. The change in SLCT(L) is still significantly different. For the PRK group, the loss without correction for spectacle magnification is 0.16 ± 0.15 logCS, or one and a half lines on the SLCT chart, (t=-4.4, p<0.001) compared to 0.27 logCS with adjustment, a difference of 11 letters or over one line. For the entire excimer group the loss without magnification correction was 0.08 ± 0.17 log CS (t=-3.1, p= 0.0035) compared to the 0.18 logCS loss measured after adjustment for magnification, again a difference of one line. At least for the population examined in this study, the standard luminance SLCT test detected subtle vision changes even without

adjustment for preoperative minification, while the HCVA and low luminance SLCT test did not.

Studies that have not taken the spectacle magnification into account have often shown improvement in visual acuity after refractive surgery. Improvement of almost one line of HCVA can be realized just by moving the refractive correction of a −10.00D myope from the spectacle to the corneal plane, depending on the initial vertex distance and assuming no additional aberrations are induced in the process [37, 38]. This would indicate that patients would improve just by switching from spectacles to rigid contact lenses. Another factor to consider is that patients who wore spectacles prior to refractive surgery do, indeed, experience a real underlying improvement in visual acuity, albeit due to magnification effects. If there is a further decrement on top of this improvement they may experience no change in performance whatsoever after surgery. On the other hand, comparing at the proper refractive plane accurately represents visual outcomes of patients who wore contact lenses prior to the surgery, whose change would then be entirely due to the refractive surgery.

2.4.4 Type of procedure versus correction

Patients who had PRK had more residual deficit in SLCT(L) performance than PARK patients. There are two basic differences between the procedures in this study that may account for the variance in performance; the PARK ablation is different and PRK patients, due to selection criteria of the FDA study, had a higher refractive error. PARK using Nidek® involves two major steps; first a spherical

ablation is completed followed by a cylindrical ablation to correct astigmatism [45]. This second ablation may serve to smooth the transition zone or increase the effective optical zone of the cornea. Corneal topographic analysis could be used to determine differences in the corneal profile of PRK and PARK procedures. Another possibility for the difference may be that the PRK group had an average of 1.73 diopters more myopic correction than the PARK group (t=2.98, p=0.0049). Studies have found that the residual loss in contrast sensitivity at six months after PRK is related to the amount of correction [14]. Both the differences in procedures and the amount of correction result in different corneal profiles and therefore corneal aberrations are expected to differ. Evaluation of corneal topography and its relation to visual performance will be addressed in Chapter 4.

The clarity of the cornea may also impact performance. A few studies have shown that performance is related to corneal haze [4, 46, 47], while other investigations have found that performance deficits and increases in haze are not coincident [22, 48]. A higher correction requires a deeper ablation to correct and consequently more epithelial healing than lesser corrections [49, 50]. The amount of healing has been shown to effect the amount of corneal haze that develops [51]. If this is the case in this study, then subjects with a higher correction are expected to develop more corneal haze. Whether this is true and how haze impacts the visual performance of subjects in this study will be address in the next chapter.

2.4.5 Spherical aberration and pupil size

Depending on luminance conditions, the subjects with larger pupils had a greater decrease in SLCT performance (see Tables 5 and 6). With larger pupils, portions of the ablation zone that detract from image formation are now involved [9, 52]. The amount of spherical aberration induced is dependent on the amount of correction, with higher corrections generally resulting in more spherical aberration [7, 53]. The effect of spherical aberration can be ameliorated if the patient's pupil size is small. Therefore, the ideal refractive surgery candidate for keratorefractive procedures that modify the anterior corneal curvature may be one with a low refractive correction and small pupils. The determination of spherical aberration induced at the anterior cornea by the various refractive surgery procedures evaluated in this study and how spherical aberration impacts visual performance will be addressed in Chapter 4.

2.4.6 Low luminance

Unlike the SLCT(L), the results of the SLCT(D) measurements did not detect as significant a loss of low contrast sensitivity after stability was reached around 6 months post-surgical. The mean postoperative loss for the combined PRK/PARK subject group was 0.14 ± 0.22 logCS (one and a half lines) on the SLCT(D) versus 0.18 ± 0.20 logCS (almost two lines) on the SLCT(L). Different mechanisms may be responsible for performance under the two conditions and, therefore, corneal changes may not have equivalent impact. Factors beyond increased corneal aberrations that affect low contrast sensitivity include corneal haze or other media

opacities and retinal sensitivity level. The impact of corneal haze may have less effect under low luminance conditions due to the nature of sub-epithelial haze and the unequal relationship of forward to backscattered light [54]. More importantly, there is less light available for scattering. Other media opacities or a decline in retinal sensitivity related to age may be responsible for a greater baseline deficit in SLCT (D) among the patients in this study than found in a previous study with younger subjects [29]. Based on Rabin's results the number of lines lost from $100cd/m^2$ to $3cd/m^2$ chart luminance is predicted to be 4 ½ lines. Preoperatively, patients in this study lost 7 ½ lines on average on the SLCT over this luminance range.

Another major factor impacted the effectiveness of the SLCT under low luminance conditions in this study: the maximum loss was often not measurable. In order to assess visual performance change after an intervention such as refractive surgery, the initial performance level on a given test needs to be such that the test has an adequate range of higher and lower performance levels available. If, for example, the best performance level on the test were attained prior to surgery, improvement would not be measurable. If, on the other hand, a low performance level is attained prior to surgery then the remaining lines on the chart limit the measurable decrement. This was the case with the SLCT(D) measurements. The mean preoperative performance level for the subjects in this study was 0.34 ± 0.17 logCS, which is the 4th line of the chart. The highest contrast line on the chart is 100% contrast, which would be 0.00 logCS. This score is achieved only when all the letters on the top line are seen. For each letter missed on the top line the score

drops by 0.01 logCS, therefore the worst possible score on the chart is –0.10 logCS. This means the maximum measurable loss would be 0.44 logCS for most subjects. However, some subjects had such poor preoperative SLCT(D) performance, near 0.00 logCS, that their loss was not measurable.

An attempt to deal with this ceiling effect was made by eliminating the pre- to postoperative performance pairs of patients who scored –0.10 logCS on the SLCT(D) postoperatively. A total of nine pairs were eliminated based on this criterion: three PARK eyes, two PRK eyes and four LASIK eyes. The mean preoperative score for this group on the SLCT(D) was 0.05 ± 0.05 logCS, which is 3 lines worse than the overall group preoperative mean of 0.34 ± 0.17 logCS. None of the ICRS eyes were eliminated. Despite this adjustment the results graphed in Figure 9 still show a trend toward greater loss with greater initial performance. This bias may have resulted from the luminance level chosen for this study or other subject factors in the population studied that led to poor baseline performance.

2.5 Conclusions

The Small Letter Contrast Test is easy to administer and easy for patients to understand since it is a familiar task. The SLCT is able to detect subtle visual changes after refractive surgery at a higher significance level than high contrast acuity testing. However, SLCT has a sampling advantage over HCVA, due to the axis of the CSF tested and the number of letters presented at each level of contrast. Therefore the higher significance level may be due to increased sampling rather than increased sensitivity of the test.

Spectacle magnification is a significant factor to account for and should be included in any assessment of visual outcomes after refractive surgery. When this factor is not considered, deficits in visual performance are underrepresented for myopes and are overrepresented for hyperopes. Low luminance testing of contrast sensitivity on the SLCT is probably best done at a higher luminance level than used in this study. The main goal of the low luminance test of contrast sensitivity was to simulate conditions in which some patients report difficulties seeing, e.g. dimly lit areas. An appropriate luminance level approximating a "dimly lit area" is needed. Normative values for the SLCT at various luminance levels by age would aid in its usefulness as a diagnostic tool.

Since it is not always practical to obtain pre- and postoperative SLCT values, an expected "normal" range would be useful for determining the visual performance level of patients who have had any type of refractive procedure. Other potential uses of the SLCT may be for military or police force entry requirements, where the SLCT may be a much finer discriminate of vision than high contrast acuity. Decreased contrast sensitivity due to any cause would be a more applicable and accurate criterion for disqualification for certain vocations than merely having had refractive surgery. It was even found in this study that some patients' contrast sensitivity on the SLCT improves after refractive surgery.

Whether there is an improvement or a decrement in performance, many factors may be responsible for visual changes after refractive surgery. Assuming no other changes in ocular structure or function for the eyes evaluated in this study after surgery, corneal clarity and shape are the most likely suspects for change in visual

performance. The relationships of corneal haze and shape changes to high contrast acuity and contrast sensitivity on the SLCT are explored in the following chapters.

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Chapter 3

Objective assessment of corneal haze and its relation to visual performance

3.1 Introduction

3.1.1 Study Goal

Corneal haze is a well-recognized consequence of surface excimer laser corneal ablation. Corneal haze results from the presence of incongruities in the corneal tissue, usually subepithelial and anterior stromal, which result in an increase in scattered light [1-6]. In clinical practice, the usual mode of evaluating corneal haze is by subjective grading based on slit lamp examination. Attempts to directly correlate corneal haze with impairment in visual performance, especially as measured by low contrast acuity or contrast sensitivity, have been mixed, however. Some studies show that performance is inversely related to the amount of haze [2, 7, 8], while other studies show that performance deficits and haze do not progress along the same time course [9, 10]. In this study, the level of haze measured by objective means will be evaluated in terms of its impact on a specific measure of visual performance, namely contrast sensitivity on the Rabin Small Letter Contrast Test (SLCT) [11].

3.1.2 Corneal clarity and visual performance

The corneal stroma maintains its clarity through the regular arrangement of collagen fibrils in a lattice-type structure in lamellar sheets. It is both the spacing of the fibrils within the arrangement and the size of the collagen fibrils that influences clarity [12, 13]. The epithelial and endothelial layers of the cornea regulate fluid and metabolite flow between the cornea and the surrounding tears and aqueous humor primarily to help maintain the fibril spacing relationship in the stroma. Unless both layers continually pump fluid out of the stroma, which naturally imbibes fluid, the cornea becomes edematous and cloudy. In fact, any distortion of the regularity of the corneal structure, through edema, mechanical forces, or degenerative processes such as keratoconus, results in a loss of clarity. Trauma is another significant cause of corneal opacification. The collagen that replaces tissue lost in a deep abrasion has a larger caliber (30-50 nanometers) than the original collagen (25-30 nanometers) [1, 6]. The larger caliber fibrils cause a change in the form of scatter and their irregular arrangement causes an increase in scatter.

Intraocular scatter has been proven to affect visual performance in numerous studies of cataract. Forward light scatter causes a veiling glare, which can have very significant effects on contrast sensitivity. Basically, the eye requires a higher contrast in order to see an object through the veiling glare. Van den Berg and Vos have studied intraocular light scatter extensively [14-17]. Their overall findings include an increase in intraocular scatter with age and a strong relation of scatter to contrast sensitivity, but a weak correlation of forward light

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scatter to high contrast acuity. The effect of corneal clarity on visual performance was first studied in depth by Hess [18, 19]. Hess evaluated the effect of edema, corneal distortion and corneal dystrophy on the contrast sensitivity function (CSF). Edema tends to cause a diffuse clouding of the cornea, while granular dystrophy causes localized areas of opacity. The resulting scatter has very different impacts on the CSF. Edema caused an overall depression of the CSF, while a granular corneal dystrophy and keratoconus caused mid- and high-spatial frequency loss and no effect on contrast sensitivity at the lower spatial frequencies.

3.1.3 Corneal haze after Photorefractive Keratectomy

In photorefractive keratectomy (PRK) using the excimer laser, the epithelium must be removed in order to ablate corneal tissue and change the anterior corneal curvature. This is usually done using a blade or excimer laser, or combination thereof, to create an epithelial defect measuring 6 to 8 millimeters in diameter. The laser then ablates Bowman's layer and the anterior stroma to create the refractive effect. After the procedure, the epithelium has to regenerate to cover the "wound."

All the usual healing sequelae associated with corneal abrasion take place after an ablation except that the bed of the abrasion is now stroma instead of Bowman's layer. During healing the anchoring fibrils of the epithelial basal cells no longer have a template to reattach to and may therefore not have the same uniformity as the original epithelial architecture [20]. In general it has been found

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that the postoperative configuration of the regenerated epithelium differs in thickness and orientation from before surgery [21, 22]. Keratocyte activation and a change in the type and regularity of collagen present in the anterior stroma are also thought to contribute to corneal haze [23-27]. In practice, it is not unusual for scarring to occur in the healing of a large corneal abrasion or ulcer. In the case of refractive surgery, scarring or haze in the ablation area is an undesirable consequence. Scarring of a moderate degree or greater may be associated with symptoms of glare or haloes or even regression of refractive effect [28-33].

Most efforts to improve PRK procedures have focused on means to reduce or eliminate haze. The homogeneity of the laser, the smoothness of the ablated surface and the depth of the ablation all seem to play a role in the development of haze [34-38]. Addressing these factors has led to improved delivery systems that leave a much more uniform stromal bed after an ablation than the earlier step-opening diaphragm systems. Despite laser advances, outcomes still depend on the human tissue response to the laser. Each individual responds differently to the ablation, so that monitoring and modulation of the healing response using anti-inflammatory agents has in some cases proven effective in reducing haze and regression [31, 39]. Other studies have shown that the effect of corticosteroids is transient, perhaps reducing initial haze and regression, but not resulting in any significant long-term benefit [40, 41].

The development of haze does not occur immediately postoperatively or even immediately after the epithelial area closes in 2 to 3 days. Epithelial activity continues after closure with a regeneration of the epithelial cell layers and a new

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basement membrane, while keratocytes in the anterior stroma activate 3 to 5 days after injury and contribute to the production of new collagen. This may be why the cornea is initially relatively clear but then develops subepithelial haze in the first postoperative months. Some studies show a Peak in haze at between one to three months, while others show the Peak as late as three to six months [9, 10, 41]. After haze Peaks there is variable resolution of the haze with time. Again, anti-inflammatory mediators and improved lasers have reduced the absolute magnitude of subepithelial haze.

3.1.4 Measurement of haze

The objective measurement of haze is superior to subjective assessments in terms of accuracy and repeatability [25, 42]. Most studies of haze after PRK have used slit lamp observation and subjective scales, in which the observer grades the presence of haze from 0 to 4 with 0 indicating no haze and 4 indicating severe haze that obscures visibility of the iris. For the present study a more precise measurement technique than subjective assessment was required since the time frame of concern is after obvious haze has resolved and slight deficits in contrast sensitivity remain. As shown in Chapter 2, even up to 12 months postoperatively a slight but significant decrease in performance on the SLCT is evident.

A few studies have incorporated objective measures of corneal haze using various instrumentations. The earliest work in this area depended on *in vitro* measurements and was aimed at determining the scattering properties of normal,

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pathological, and aging corneas [12, 13, 43]. Allen and Vos (1967) used a microdensitometer to analyze black and white photographs of the human cornea *in vivo* taken with a slit lamp camera [14]. The back-scattered light from the cornea and lens was not found to correlate with visual performance changes with age. Olsen (1982) improved on this clinical method by adding a fiber optic probe and photomultiplier unit to the slip lamp camera system [44]. The scattered light from a 160μm wide slit beam focused on the cornea was recorded and analyzed. Through this study it was determined that corneal scatter increases with age. Localization of scatter to specific corneal layers or regions was not possible with this technique, however.

The Scheimpflug photographic technique is a procedure that has been successfully used in human crystalline lens studies to take very accurate cross-sectional images. The major advantage of Scheimpflug over other imaging techniques is that the entire depth of the structure imaged is in focus. In 1990, Smith, et al applied the technique to corneal analysis using computerized linear scanning densitometry to measure Scheimpflug photographs and found that for the central cornea there was no correlation between scatter and patient age [45]. The main improvement over slit lamp methods was the ability to accurately determine that the anterior and posterior corneal layers are the principle contributors to corneal scatter. A technique that does not involve multiple analysis steps was needed, however. In 1995, Soya, et al modified an anterior segment Scheimpflug imaging system (EAS-1000, Nidek®, Japan) to capture and analyze the cornea using computerized densitometry of the video image

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[46]. The imaging system, prototype TSPC-3, used in the present study is a further modification of the EAS-1000 in terms of anterior segment magnification and analysis programs. Similar instrumentation has already been used to assess wound healing after PRK [47] and to evaluate the transparency and barrier functions of the cornea [48].

When back-scattered light, seen as haze to the observer, is correlated to forward light scatter, measured haze is expected to correlate to contrast sensitivity. A study by Soya, et al confirmed the relationship between back-scatter, as measured by the TSPC-3, and forward scatter and transmitted light for particle suspensions of sizes comparable to normal and abnormal corneal components, as measured by a U-2010 Spectrophotometer (Hitachi, Japan), (Soya, K. 1999, in publication). The type of haze measured by slit lamp evaluation is primarily subepithelial haze. Deeper haze may also have an impact on performance, so in this study both subepithelial and full corneal thickness haze are measured. If measured haze is not correlated to visual performance, then corneal aberrations or other factors may be implicated. The subject pool will include some non-surface excimer procedures to aid in the evaluation of the alternative theories of haze versus corneal aberrations on visual performance after refractive surgery.

3.2 Methods

3.2.1 Subjects

Photorefractive keratectomy was performed on 28 patients (44 eyes) in the FDA phase III trials of the NIDEK® EC-5000 Excimer Laser Corneal Surgery System (Gamagori, Aichi 443 Japan; Fremont, CA). Nineteen eyes had Nidek PRK and 24 eyes had Nidek PARK (astigmatic PRK). One of the patients had PRK using the VISX® laser on her second eye. A total of 44 eyes having had excimer laser refractive surgery were therefore evaluated. The refractive correction procedure consisted of instillation of topical anesthetic and antiobiotic preoperatively, mechanical scrape of the epithelium, and ablation of Bowman's layer and the anterior stroma according to the Nidek EC-5000 algorithm. Postoperatively topical antibiotics are instilled and a bandage contact lens applied. The patient continued to use topical antibiotics as prescribed and topical non-steroidal anti-inflammatories (NSAIDs) and/or oral analgesics as needed for pain until the epithelium had closed over the ablated area. The bandage lens was removed, topical steroids added to the regimen and topical antibiotics phased out. Corticosteroids were continued for approximately three months depending on the individual healing response in terms of refractive stability and haze development.

The mean refractive correction for the PRK group was −7.5 ± 2.1 diopters and the mean correction for the PARK group was −6.5 ± 1.5 diopters of sphere with 1.5 ± 0.9 diopters of cylinder. Patients were examined preoperatively (n=44)

for baseline and at 1 month (n=19), 3 months (n=36), 6 months (n=35), 9 months (n=26), and 12 months (n=17) months postoperatively. For analysis after the most significant corneal healing has stabilized, a subgroup of 42 eyes with both preoperative and six or more months postoperative data available was used. This group included four eyes beyond 12 months with a mean postoperative period of 10 ± 4 months for the subgroup. Preliminary results of five LASIK (mean correction -6.8 ± 1.3 diopters; mean follow-up 2.2 months) and two ICRS eyes (corrections of -2.75 and -3.25 diopters; follow-up of 9 and 2 months) are presented for comparison since these procedures are not expected to produce central haze.

3.2.2 Measurement of visual performance

At each visit, Snellen high contrast visual acuity was measured after manifest refraction and contrast sensitivity was measured using the Rabin Small Letter Contrast Test (SLCT) under standard luminance conditions. Visual acuity was recorded in logMAR with credit given for letters seen based on their relative value in their acuity line. Contrast sensitivity on the SLCT was measured at 3.3 meters with a chart luminance of 100 cd/m^2. The letters subtended 8 minutes of arc and the letter details subtended 1.6 minutes of arc (20/32 equivalent). Because patients wore their manifest refraction in a trial frame, spectacle magnification was taken into account, especially preoperatively. All visual performance measures were adjusted for spectacle magnification as described in Chapter 2.

3.2.3 Measurement of corneal haze

Haze was measured objectively at each visit. A prototype haze meter (TSPC-3, Nidek®, Japan) based on the Scheimpflug technique was used to capture cross-sectional images of the cornea. The instrument's main improvements over the EAS-1000 (Nidek, Inc., Japan) are the larger magnified image and the increase in corneal analysis options. The Xenon flash slitbeam and the camera are adjustable to allow capture along any meridian. The images of the 45-degree and 135-degree meridians were chosen to sample the corneal surface. The 90-degree cross-section is affected by mild opacification of the cornea that develops under the upper lid, especially with age or soft contact lens wear. Using all four positions, 45, 90, 135 and 180, takes more time to complete and does not provide significantly more information about corneal haze than using just the 45-135 degree combination (Soya,K. 1997, unpublished Nidek study). The slit dimensions were 0.08 by 7 millimeters, adjustable to smaller lengths to avoid capturing iris or peripheral corneal reflections. A 6.0-millimeter cross-section of the cornea at both meridians was captured by the CCD camera and digitized for analysis.

The back-scattered light from corneal haze or other optical irregularities produces areas of increased intensity in the image. The unit of measure for the intensity levels in the image is the CCT (Computer-Compatible Tape), used for recording digitized grayscale values in computerized image analysis. The image was analyzed in two ways. Peak haze is found by tracing along the maximum

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intensity of the corneal cross section. The Peak haze in the central 3.5-millimeter and 5.5-millimeter zones was measured. The mean of the 45 and 135-degree meridians was determined for each of the zones. Integral haze involves the entire depth of the cornea; therefore all corneal structures that scatter or reflect light are included in the Integral haze measurement, including subepithelial haze and stromal haze. Again, the 3.5-millimeter and 5.5-millimeter zones were measured and the mean of the two meridians determined for each zone.

3.2.4 Data Analysis

The progression of Peak and Integral haze was evaluated longitudinally to determine the time course and amount of haze development and recovery. The region of the cornea may also be important, so analysis was completed separately for the 3.5-millimeter and 5.5-millimeter diameter zones. The zones were then compared to determine whether haze was evenly distributed over the analyzed area or confined to the smaller zone. The corresponding performance on the SLCT and HCVA at each time interval was evaluated to determine the relative impact of corneal haze. Peak haze and Integral haze were evaluated separately to see which measure best corresponds to visual performance. Finally, individuals with residual Peak or Integral haze at one month and at stability, defined as the latest examination 6 or more months postoperative, were analyzed to determine whether visual performance is affected.

3.3 Results

3.3.1 Longitudinal results for Peak and Integral haze

Figure 1 shows the mean Peak haze measurements for the combined

PRK and PARK subject group at each visit. The maximum Peak haze value

occurs at one month and then declines and stabilizes near preoperative levels by

three to six months. The difference from preoperative values is only significant at

the one month visit (paired t-test = 3.12, p=0.005).
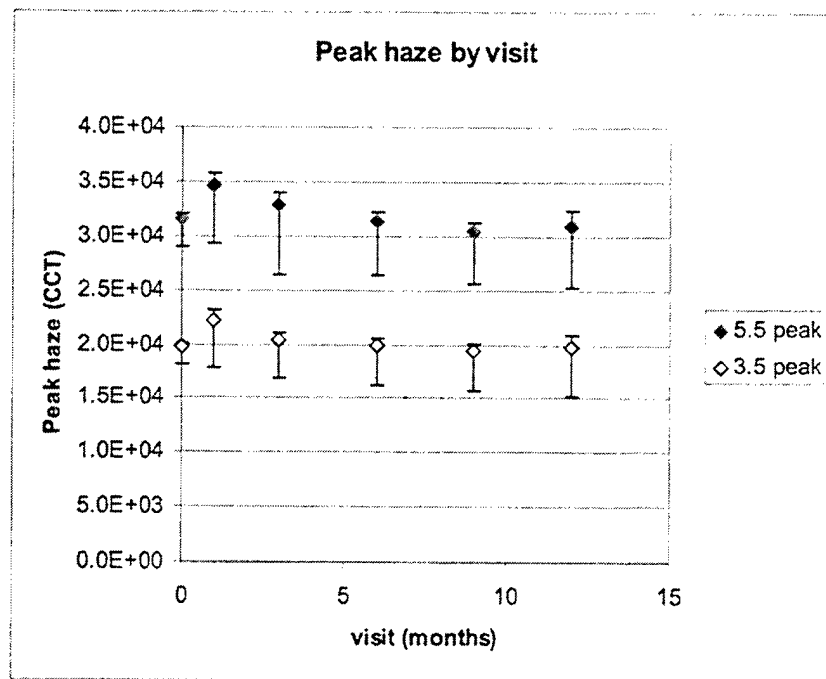
Figure 1: Mean values for Peak haze for both the 3.5 and 5.5-millimeter zones are plotted by visit. The upper bars on each point standard error, while the lower bars indicate standard deviations. The unit for Peak haze is a digitized measure of image intensity in the trace based on the Computer Compatible Tape (CCT). Peak haze is highest at one month and returns to baseline by 3 months for the 3.5-mm zone and by 6 months for the 5.5-mm zone.

Mean Integral haze by visit for both zones is plotted in figure 2. At one month there is a slight decline (paired t-test = -1.81, p=0.08) from preoperative Integral haze. From one to three months Integral haze decreases, becoming highly significant at three months (paired t-test = -4.6, p<0.0001) and remaining essentially unchanged between three and twelve months.
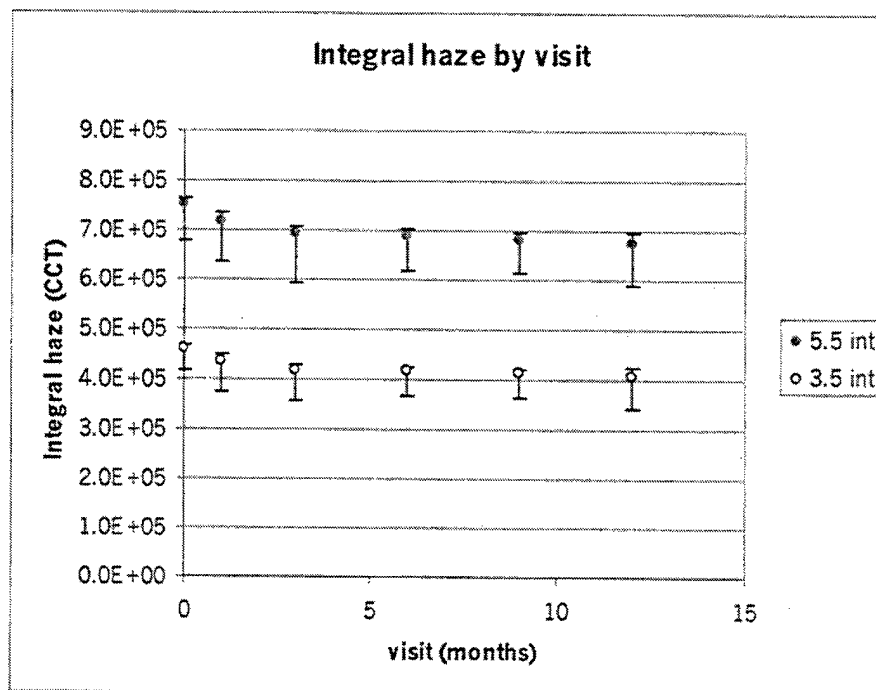
Figure 2: Mean Integral haze, standard errors (upper bars) and standard deviations (lower bars) for both measured zones are plotted by visit. Integral haze decreases at the first month visit and continues to decline for both zones to the three-month visit. Thereafter there is no significant decrease in Integral haze.

An example case using photographs taken by the hazemeter at the preoperative examination and the one month and one year postoperative examinations is provided in Figure 3. The subject represented in this figure had PRK to correct -9.00 diopters of myopia. The increase in Peak haze from baseline is evident at the one-month examination and has completely resolved by the one-year examination. The only evidence of refractive surgery is the

reduction in corneal thickness from baseline; a factor in the reduction of Integral haze.
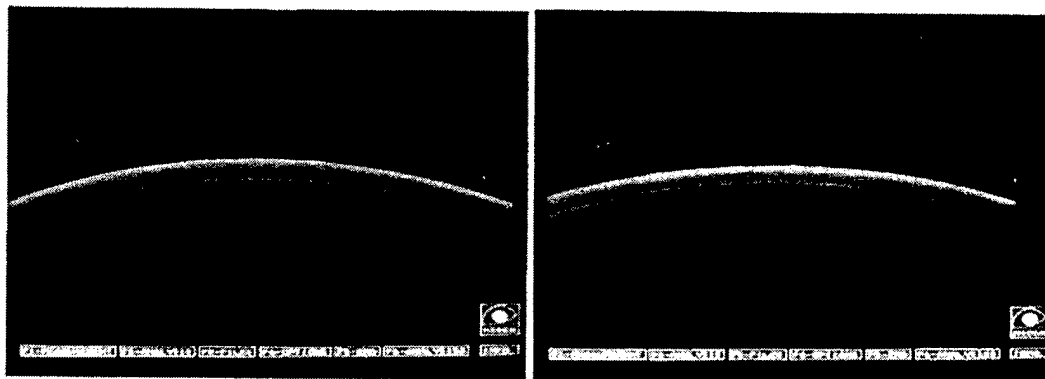
A. Pre-operative   B. One month
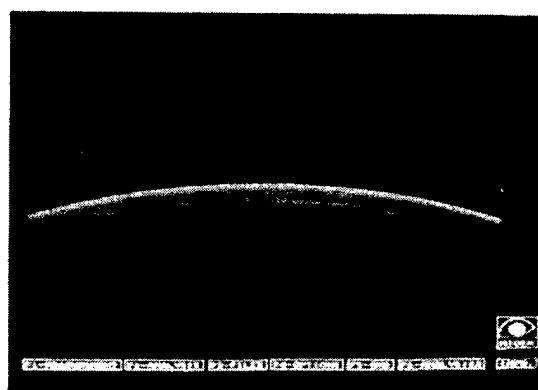
C. One year

Figure 3: Three cross-sections of one eye at three intervals, pre- and one month and one year postoperatively. From pre-op (panel A) to one month (panel B) postoperative, the most apparent changes are the increase in intensity at the anterior cornea and the decrease in central corneal thickness. By one year (panel C) the anterior corneal haze has cleared and the only difference from pre-op is the decrease in thickness.

3.3.2 Area of corneal haze

The 3.5-millimeter zone is contained within the 5.5-millimeter zone, constituting 40% of the larger area. Pre-operatively, both Peak and Integral haze measures of the smaller zone are 63% of the larger zone, indicating that haze is naturally denser centrally. At the one-month postoperative exam and extending

through the latest exam period, both the Peak and Integral haze measures of the smaller zone continue to be 63% of the larger zone measures. Additionally, the 3.5 and 5.5 millimeter zones are highly correlated for both the Peak and Integral haze measures ($r = 0.99$). Based on these findings, changes in haze are considered to be proportional across the cornea and not localized to either the central or more peripheral corneal areas. Subsequent analysis of haze and visual performance is therefore based on haze measurements of the 3.5-millimeter zone.

3.3.3 Peak Haze and visual performance

Figure 4 shows the change from baseline in visual performance in HCVA and on the SLCT and the change in Peak haze at each examination for the surface excimer group. To facilitate comparison, the haze values have been converted to $\log_{10}$ haze and the visual performance measures have been plotted so that performance decrements correspond to negative values on the y-axis. Peak haze is maximum at the one-month postoperative examination. This corresponds to the greatest decrement in both HCVA and SLCT performance. As was presented in section 3.3.1, Peak haze returns to baseline by six months postoperative. HCVA and SLCT do not return to baseline at any postoperative interval in this study, however (see Chapter 2).

Peak haze and visual performance
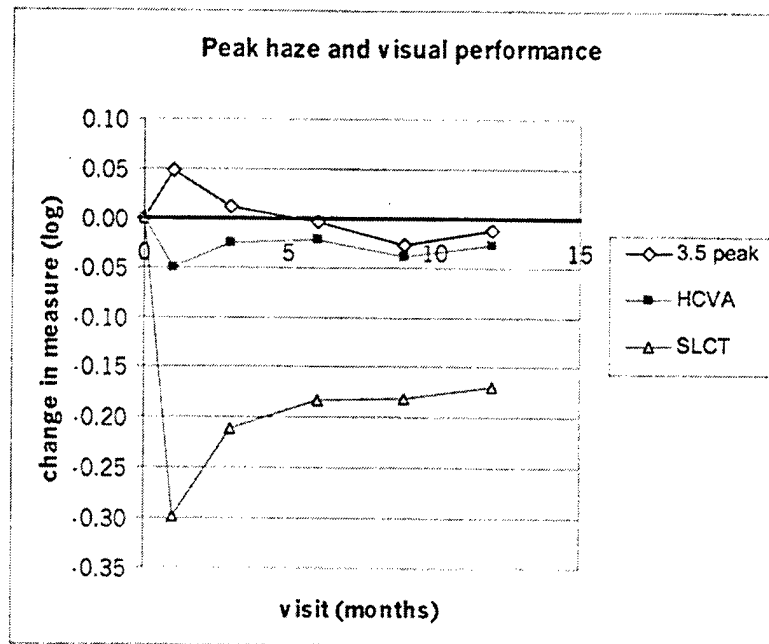
Figure 4: The change in the visual performance and Peak haze measures are plotted by visit. All measures are plotted in log values to ease comparison. The dark line indicates "baseline." Both HCVA and SLCT decrease at the first month visit, while Peak haze increases. The mirror-like pattern of haze versus performance seems to indicate a relationship that is strongest at one month. By three months, haze has returned to baseline, while the visual performance measures continue to show a deficit (only 50% recovery from the initial loss at one month).

Figure 5 shows the change in Peak haze from preoperative level at the one-month and the latest examination after stability is reached (10 ± 4 months). At one month 68% of eyes (13/19) have an increase in Peak haze and at stability only 15% of eyes (6/38) have increased Peak haze. To determine if the change in Peak haze is predictive of visual performance, the eyes with increased haze were analyzed. At one month only 78% of eyes (10/13) with increased Peak haze had decreased HCVA and 92% of eyes (12/13) had decreased SLCT performance. At stability 5 of the 7 eyes with increased Peak haze had decreased HCVA and 6 of the 7 eyes performed worse on the SLCT. One of the 7 eyes experienced an increase of 0.93 logHaze from preoperative level and was

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not plotted in the figure. The subject (PM) did not heal properly in the early

postoperative period and developed a significant amount of haze and 3 diopters

of regression. This eye had a decrease in HCVA of 0.24 logMAR and a decrease

in SLCT of 0.52 logCS. Another eye had an increase of 0.221 logHaze, which is

greater than two standard deviations from the mean change in haze of −0.02 ±

0.06 logHaze. However, this eye had improvements from baseline in both HCVA

and SLCT by 0.06 logMAR and 0.08 logCS, respectively. Specifics for all the

subjects with increased Peak haze and the one subject with a decrease in Peak

haze greater than two standard deviations from the mean are provided in Table

1.
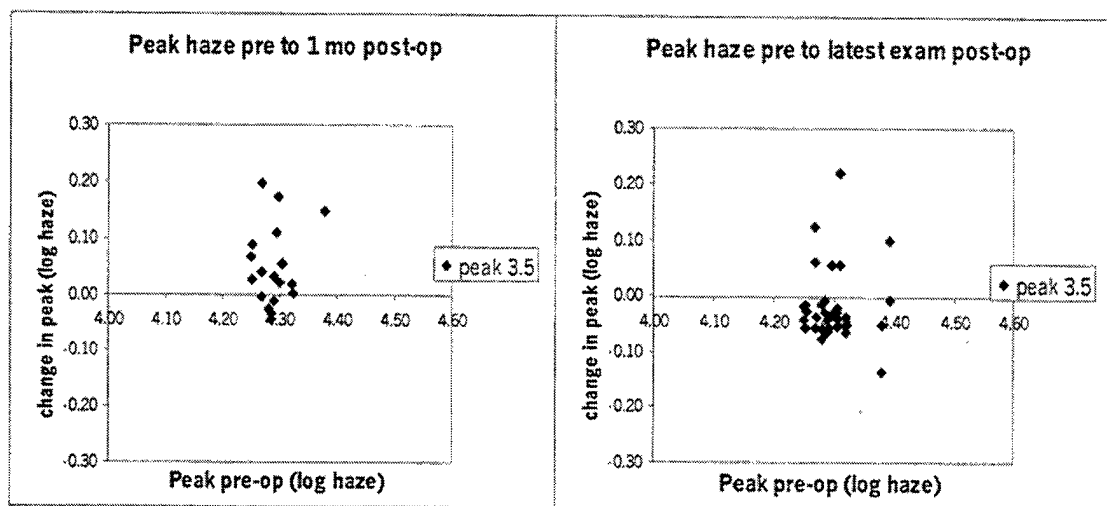
Figure 5: These two graphs show the change in Peak haze from preoperative levels for both the one-month postoperative visit (left panel) and the latest postoperative (right panel) examination. At one month, most eyes are an increase in Peak haze with a few eyes showing less Peak haze than preoperatively. By the stability (10 ± 4 months), most eyes have less Peak haze with 6 eyes measuring more haze than preoperatively (see Table 1).

Table 1
Changes in performance for eyes with increased Peak haze at stability

Subject	Peak (logHaze)	HCVA (logMAR)	SLCT (logCS)
PM	0.931	-0.24	-0.52
LM (OS)	0.221	0.06	0.08
SPX (OS)	0.124	-0.04	-0.27
JN	0.101	-0.07	-0.20
SPX (OD)	0.063	-0.04	-0.29
LM (OD)	0.056	0.06	-0.08
CE	0.056	-0.06	-0.15
WE	-0.135	0.09	0.03

For all eyes at the two time intervals, the change in haze is correlated to the change in performance as detailed in Table 2. Negative correlations correspond to a decrease in performance with an increase in haze. The highest correlation exists for the change in HCVA with the increase in Peak haze at one month, however the correlation is not very strong. None of the correlations are statistically significant.

Table 2
Correlation (r) of Peak haze and visual performance changes

change in:	HCVA	SLCT
Peak (1 month)	-0.13	0.03
Peak (stability)	-0.03	-0.01

3.3.4 Integral Haze and visual performance

Figure 6 depicts the change in Integral haze from baseline plotted with the change in performance. Unlike Peak haze, Integral haze decreased postoperatively for the surface excimer group and the pattern of change is not consistent with the pattern of visual performance change.

Integral haze and visual performance
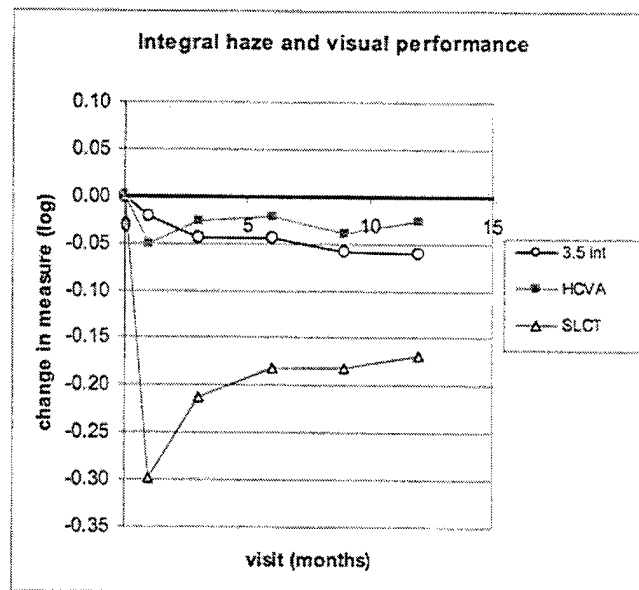
Figure 6: Mean Integral haze (open circles) and visual performance changes are plotted by visit. The dark line indicates "baseline." Integral haze decreases postoperatively, stabilizing by the three-month examination. Both visual performance measures decrease at one month and recover between three and six months postoperative. The decrease in performance corresponds to a decrease in Integral haze at one month, with Integral haze continuing to decrease during the recovery of visual performance between one and six months.

Figure 7 shows the change in Integral haze from baseline at the one-month and latest postoperative examination. At one month the change in Integral haze is evenly distributed between increased and decreased haze. The mean change in Integral haze at one month is −0.02 ± 0.05 logHaze with 58% of eyes (11/19) measuring less Integral haze than preoperatively. By the latest postoperative examination, 95% of corneas (40/42) have less Integral haze than preoperatively. Factors contributing to this decrease will be addressed in the Discussion.
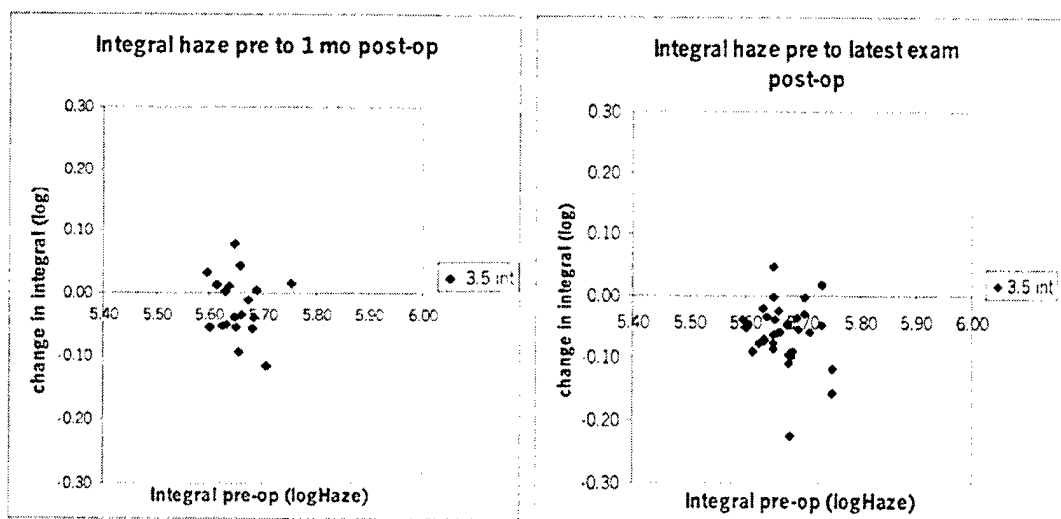
Figure 7: Change in Integral haze from preoperative levels for the one-month (left panel) and latest postoperative (right panel) examinations. At one month the changes are evenly distributed between increased and decreased haze. By stability (10 ± 4 months postoperative), all except two corneas have less Integral haze than preoperative measures.

The predictive value of Integral haze changes was determined for the eyes with increased haze. At one month of the eight eyes with increased Integral haze, 7 had a decrease in HCVA and 6 had a decrease in SLCT. At stability only 3 eyes had a residual increase in Integral haze. Again, subject (PM) experienced the greatest increase in haze. All of these eyes had deficits from baseline in HCVA and SLCT as outlined in Table 3. All three subjects had increased Peak haze and were previously noted in Table 1. One subject experienced a decrease in Integral haze greater than two standard deviations below the mean and is also listed in Table 3. Note the eye with decreased Integral haze experienced decreased visual performance comparable to the eyes with increased Integral haze.

Table 3
Changes in performance for eyes with increased Integral haze at stability

Subject	Integral (logHaze)	HCVA (logMAR)	SLCT (logCS)
PM	0.627	-0.24	-0.52
SPX (OS)	0.047	-0.04	-0.27
JN	0.017	-0.07	-0.20
JH	-0.226	-0.06	-0.27

The correlations between the changes in Integral haze and visual performance for the whole group at both time intervals are provided in Table 4. Negative correlations indicate a decrease in performance with an increase in Integral haze. The correlation for HCVA changes is in keeping with expectations, while the correlation for SLCT change seems to indicate an increase in performance with an increase in Integral haze. None of the correlations are significant, however.

Table 4
Correlations (r) between changes in Integral haze and visual performance

change in:	HCVA	SLCT
Integral (1 month)	-0.17	0.15
Integral (stability)	-0.15	0.08

3.3.5 LASIK and ICRS

Pre- and postoperative measurements of haze were only available for five LASIK and two ICRS eyes. The results provided are, therefore, preliminary and only useful when compared to the surface excimer group results. Table 5 details

the mean and standard deviations of the changes in haze and visual
performance measures for the LASIK and ICRS eyes.

Table 5
Changes in haze and visual performance measures

change in:	Peak logHaze (sd)	Integral logHaze (sd)	HCVA logMAR (sd)	SLCT logCS (sd)
LASIK	0.011 (0.01)	-0.019 (0.01)	-0.075(0.08)	-0.358(0.19)
ICRS	0.006(0.01)	0.005(0.02)	0.029(0.07)	-0.192(0.18)

Peak haze remains relatively unchanged from preoperative levels for both
procedures. Integral haze is unaffected by the ICRS procedure, however there is
a statistically significant decrease after LASIK (paired t-test = -3.04, p<0.04).
There was a statistically significant decrease in HCVA for the LASIK eyes (paired
t-test = 3.99, p=0.0003), while one ICRS eye improved and the other lost HCVA.
A statistically significant decrease in SLCT performance was measured for both
LASIK (paired t-test = 3.31, p=0.002) and ICRS (paired t-test = 2.71, p=0.03).
Performance was not correlated to Peak or Integral haze.

3.4 Discussion

3.4.1 Haze and visual performance (surface excimer procedures)

In this study Peak haze increased after surface excimer procedures,
reaching a maximum at one month and returning to baseline by three. The
maximum amount of Peak haze may have occurred before or after this time

interval, however the protocol of this study limited measurements to the postoperative time intervals outlined in the Methods section. By design, excimer procedures achieve their refractive effect by reducing corneal thickness. Integral haze, which is a measure of haze through the full thickness of the cornea, is therefore expected to decrease merely due to the decrease in corneal thickness. The results as detailed in Figure 2 support this logic. Integral haze includes the effect of Peak haze, therefore as Peak haze resolves from its maximum at one month, Integral haze decreases accordingly.

The change in Peak haze at one month and Integral haze at both one month and stability correlates with changes in HCVA, however the correlation is not strong. The correlation of haze changes to SLCT changes is poor for Peak haze and likewise poor and counterintuitive for Integral haze. In other words, the correlation seems to indicate a tendency for there to be improved SLCT performance with increasing Integral haze.

The relationship of Peak haze to performance appears clear from the plot in Figure 4, where HCVA and SLCT performance are most affected when Peak haze is maximum at one month. Since Peak haze resolves to baseline by six months while both visual performance measures fail to return to baseline, the differential in performance at one month versus stability is most likely due to subepithelial haze. The proportion of visual performance differential from one month to stability is 50% for both HCVA and SLCT, meaning that 50% of the loss evident at one month is regained by the latest examination. At stability the residual performance decrement is most likely due to factors other than corneal

haze, such as induced aberrations or healing process residuals too small to measure using the present technique.

3.4.2 Procedural differences (LASIK and ICRS)

Compared to the time course of haze development after surface excimer procedures, the eyes in this study that had LASIK or ICRS maintained clarity at the preoperative level in the central 3.5-millimeter zone postoperatively. This is primarily due to the difference in the healing processes after these procedures. After LASIK, the stroma-stroma interface of the corneal flap heals by reestablishing adhesions and the epithelium at the flap margin seals the gap to restore corneal epithelial integrity. Corneal clarity therefore depends on an even flap interface, non-aggressive stromal healing and proper interdigitation of the healing epithelium. In this study haze was only detectable at the flap margin using a slit lamp evaluation since the flap edge diameter, 8.5 millimeters, is well outside the 6.5-millimeter zone measured with the TSPC-3. The decrease in Integral haze after LASIK is most likely due to the decrease in corneal thickness after stromal ablation.

The ICRS arcs are implanted into two lamellar channels at two-thirds corneal depth with approximately 6 to 7 millimeters between the inner edges of the segments. Healing that takes place after implantation consists of closure of the vertical incision in the superior cornea used to gain access to the deeper stroma to create the lamellar channels and any localized response within the channels. Channel haze occurs due to a deposition of extracellular material,

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proteoglycan macromolecules and collagen fibrils of various diameters along the edges of the ICRS arcs in the potential space created by the vaulting action of the arc [49]. Figure 8 is an off-axis image of the ICRS segment taken with the TSPC-3.
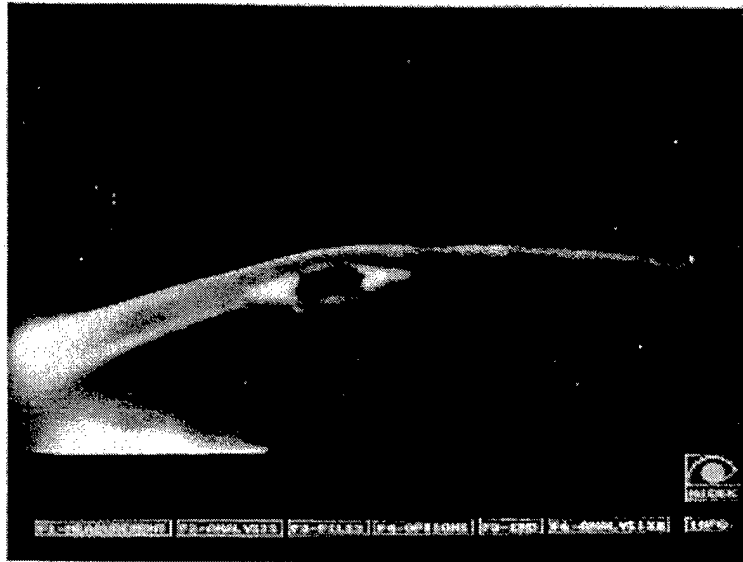
Figure 8: Off-axis image of the ICRS. In this figure the channel haze is evident on either side of the ring. The high-intensity areas at the edge of the image are due to reflections from the iris and limbal regions.

Channel haze is detectable with slit lamp evaluation and at the edges of the images captured with the hazemeter; therefore it is near the 6.0-millimeter diameter range and is potentially only a visual factor when the pupil is dilated. Since the central cornea is not directly modified in the ICRS procedure, Integral haze would not be expected to change, as was found in this study. With no change in Peak haze for either procedure, but a decrease in both HCVA and SLCT performance, further evidence is provided that visual performance changes are due to factors other than corneal haze.

3.5 Conclusions

The TSPC-3 objective hazemeter used in this study provides a quantitative measure of corneal clarity. The technique is non-invasive and it takes less than one minute per eye to capture the two images required for analysis. A comparison with subjective slit lamp assessment of haze was not completed since previous studies had already shown that objective assessments are superior. Anecdotally, very subtle changes in haze levels were detectable using the hazemeter, while it was difficult to make the same determination using slit lamp evaluation. Another benefit of the TSPC-3 was the ability to demonstrate resolution of haze to the patient and other practitioners using side-by-side comparison of corneal cross-sections from various examination periods.

Hazemeter measurements confirm that after surface excimer procedures using the Nidek EC-5000, the corneal response includes the development of haze. The haze is confined to the deep epithelial and anterior stromal region of the cornea, as determined by the location of the Peak haze trace of the corneal cross section (see Figure 1). Either due to smoothness of the ablation or suppression of the healing response using topical corticosteroids or a combination of both factors, corneal haze mostly dissipated by three months and had returned to baseline or better for 85% of subjects by stability. If haze were the only factor affecting visual performance, then HCVA and SLCT results would have returned to baseline at the same rate. Additionally, the six subjects who had any residual Peak haze at stability would have had decreased visual performance. This is not what was found. For both of the non-surface excimer

procedures, LASIK and ICRS, a performance decrement similar to that found after surface excimer procedures exists in the presence of clear corneas.

Given a normal postoperative course, all evidence seems to vindicate haze; it is not the primary source of persistent visual disturbances after the keratorefractive procedures evaluated in this study.

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Chapter 4

Corneal Shape and Optics after Keratorefractive Surgery

4.1 Introduction

4.1.1 Background and Aim of Study

Advances in corneal topography and keratorefractive surgery are closely linked. The ability to measure the corneal surface is beneficial to improving the accuracy of refractive surgery procedures. Likewise, improvements in refractive surgery demand greater precision in corneal measurement. The cornea is the primary refracting surface of the eye. As such, the changes to corneal shape induced by keratorefractive procedures are bound to affect the image-forming properties of the cornea. The subject of this chapter is an evaluation of how various procedures, such as photorefractive keratectomy (PRK), astigmatic PRK (PARK), laser in-situ keratomileusis (LASIK) and the intra-stromal corneal ring segments (ICRS), change the shape and optics of the cornea as measured by corneal topography.

Corneal topography provides much more information about the quality of the refractive contribution of the anterior cornea to the eye than either keratometry or photokeratoscopy. Topographers offer many approaches to analyzing the corneal surface. Three main measures were used in this study. First, the topographic indices, which are quantitative measures of surface characteristics and include measures of predicted visual acuity, were analyzed to determine how they change after refractive surgery and their relationship to

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visual performance. Then corneal surface reconstruction using the data files of ring locations and height from topography was used to determine changes in centration and size of the optical zone after ablation and how these correspond to vision. Finally, the image-forming properties of the anterior cornea were represented in terms of the point spread function and the modulation transfer function and these were related to visual performance.

4.1.2 Topographic indices

Topographic indices to quantitatively describe the corneal surface have been used primarily to detect and categorize the severity of keratoconus [1-6]. Although moderate and advanced cases of keratoconus are easy to identify using slit lamp evaluation and keratometry, early keratoconus is sometimes more difficult to detect. Early detection has become more critical, however, since it is felt that some keratorefractive procedures may stimulate a more rapid progression of keratoconus [7-9]. Consequently, screening refractive surgery candidates for keratoconus using corneal topography has become a routine practice. Topographic indices may also be used to aid in evaluation of the cornea for contact lens fitting, for adjustment of sutures after penetrating keratoplasty (PKP) or cataract surgery and for analysis of the cornea before and after keratorefractive procedures.

The TMS-2™ topographer used in this study offers a number of topographic indices for description of the shape, surface quality, and optics of the anterior cornea. The indices that describe surface shape include the Surface

Asymmetry Index (SAI) and the Corneal Eccentricity Index (CEI). The SAI compares points across the cornea, so in refractive surgery it should be sensitive to the centration and symmetry of the ablation area. The Corneal Eccentricity Index (CEI) describes the overall corneal shape as it relates to an ellipsoid. In normal corneas, the CEI is positive as in a prolate ellipsoidal surface. After most keratorefractive procedures it becomes negative or oblate. The net result is a change in the aberration structure of the cornea and therefore the eye. The main descriptor of corneal surface quality is the Surface Regularity Index (SRI). The SRI looks for regularity along each meridian so it should be more sensitive to sudden changes in power as is found in the transition zone or irregularities in the optical zone such as central islands. Two indices address the optical quality of the cornea, the Irregular Astigmatism Index (IAI) and the Coefficient of Variation of Corneal Power (CVP). The IAI gives a measure of residual uncorrectable astigmatism, which may decrease best spectacle-corrected visual acuity. The CVP is an index of the range of powers of the anterior cornea: the greater the range, the more difficult the eye may be to correct with standard spectacle correction.

Beyond detection of surface distortions, it is important to know what quality of vision to expect from a particular cornea. Many topographers attempt to make this prediction using various methods to evaluate the optics of the corneal surface [10]. The TMS-2™ topographer used in this study determines potential visual acuity (PVA) using the regularity and symmetry of the cornea. A study by Wilson and Klyce used the SRI and SAI indices to evaluate corneas

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with a variety of conditions, including corneal transplants, keratoconus, and radial keratotomy, but not including excimer laser refractive surgery [11]. They found a correlation of $r = 0.80$ between SRI and best spectacle corrected visual acuity (BSCVA) and $r = 0.62$ for SAI and BSCVA. An unpublished study by Soya (1998) found a lower correlation for SRI and a higher correlation for SAI and high contrast visual acuity (HCVA) for patients who had PRK (SRI, $r = 0.68$; SAI, $r = 0.78$). Three possible explanations exist for the difference between this result and the previous study. First, the corneal changes of the populations measured were different. Second, HCVA after PRK is generally good, resulting in a limited range of visual acuities and third, PRK surface changes beyond the central cornea are often dramatic, resulting in elevated indices. It may therefore be more important to have indices that predict more sensitive measures of vision, such as contrast sensitivity rather than high contrast acuity. There are very few studies evaluating the predictive capabilities of these indices after refractive surgery. The initial evaluation in this study will be of the ability of the current TMS indices to predict HCVA as well as SLCT performance after refractive surgery.

4.1.3 The Effective Optical Zone

Corneal maps often reveal subtleties of the surface not highlighted by the existing corneal indices. Clinicians customarily use multiple diagnostic tools to fully evaluate a condition, so visualization using corneal maps will probably continue to play an important role. The key to understanding the corneal surface after refractive surgery is in the appropriate use of the various representations

available. The axial curvature map is the most common map used, but because it tends to average out changes in curvature of the surface it tends to underrepresent curvature changes after refractive surgery. The maps that may provide the best visualization of the corneal surface after keratorefractive surgery are the refractive and the instantaneous maps. The refractive map shows the refractive power of the cornea taking into account the non-paraxial optics of the peripheral cornea. This map can be used to determine the size and centration of the optical region of the cornea.

The transition zone is the region of high curvature that occurs between the edge of the optical portion of the ablation zone and the extreme edge of the ablation zone. It is often lost in the axial representation. The tangential, also known as the instantaneous, curvature map is able to capture the quickly changing curvature of the transition zone, so it is useful for determining the location of the transition zone in terms of slope and radius from the center. Evaluation of the transition zone will not be included in this paper, except in the manner in which it impacts on the optics of the cornea.

Numerous studies have looked at the topographic changes after refractive surgery to determine the quality of the surface, characteristics of the transition zone, or centration of the ablation zone [12-22]. Decentration of the ablation zone has been associated with a decrease in visual performance, both contrast sensitivity and high contrast acuity. More decentration is necessary before effects on high contrast acuity become apparent. Although the ablation diameter is often considered in terms of effect on visual outcome [23-26], very few studies

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have looked at the size of the ablation zone in terms of optics. Once the cornea has healed and depending on the amount of correction, the effective optical zone (EOZ) can be significantly smaller than the ablation diameter of six of more millimeters.

The EOZ is introduced in this study as a measure of the area of the cornea within a given refractive power (in diopters). The region outside the EOZ represents portions of the cornea, which detract from image clarity in the form of aberrations such as positive or negative spherical aberration. Therefore, the larger and more accurately centered the EOZ is with respect to the pupil size and center, the better the anticipated visual performance. In this study, surface reconstruction using a Taylor expansion of height and ring position data from the TMS-2™ will be used to determine the refractive properties of the cornea and the properties of the EOZ before and after refractive surgery. The EOZ centration and size will then be evaluated in terms of the relationship of each to HCVA and contrast sensitivity on the SLCT.

4.1.4 Corneal Image-forming Properties

Another aspect of corneal evaluation involves assessment of the image-forming properties of the cornea. Ray tracing of the corneal topography is a technique that allows visualization of the quality of focus at the focal plane of the corneal surface . Hemenger, et al (1995) analyzed corneal optics by using corneal topography to produce the point-spread function (PSF) and wavefront error plots [27]. A study by Maguire, et al (1991) showed that ray tracing of

corneal topography could be used to predict visual acuity [28]. The PSF of the eye has been shown to relate to detail detection of annuli and thin lines [29-31].

At the focal plane, the density of points at each location is represented by the PSF. Figure 1 shows four PSF plots corresponding to the PSF of an ellipsoid, a sphere, a normal cornea with a large pupil, and the same cornea with a small pupil. All surfaces were captured using the TMS-2. The peak is highest for the ellipsoid shape and lowest for the spherical shape. The tail region is most obvious around the spherical shape, corresponding to very significant effects of spherical aberration. The main difference between the two PSF's of the normal cornea is the increase in points falling outside the central peak forming a more obvious tail in the large pupil condition. The peak remains unchanged with the change in pupil size. The peak and width of the PSF are expected to positively correlate to HCVA while the tails of the point spread function are anticipated to negatively correlate to performance on the SLCT.
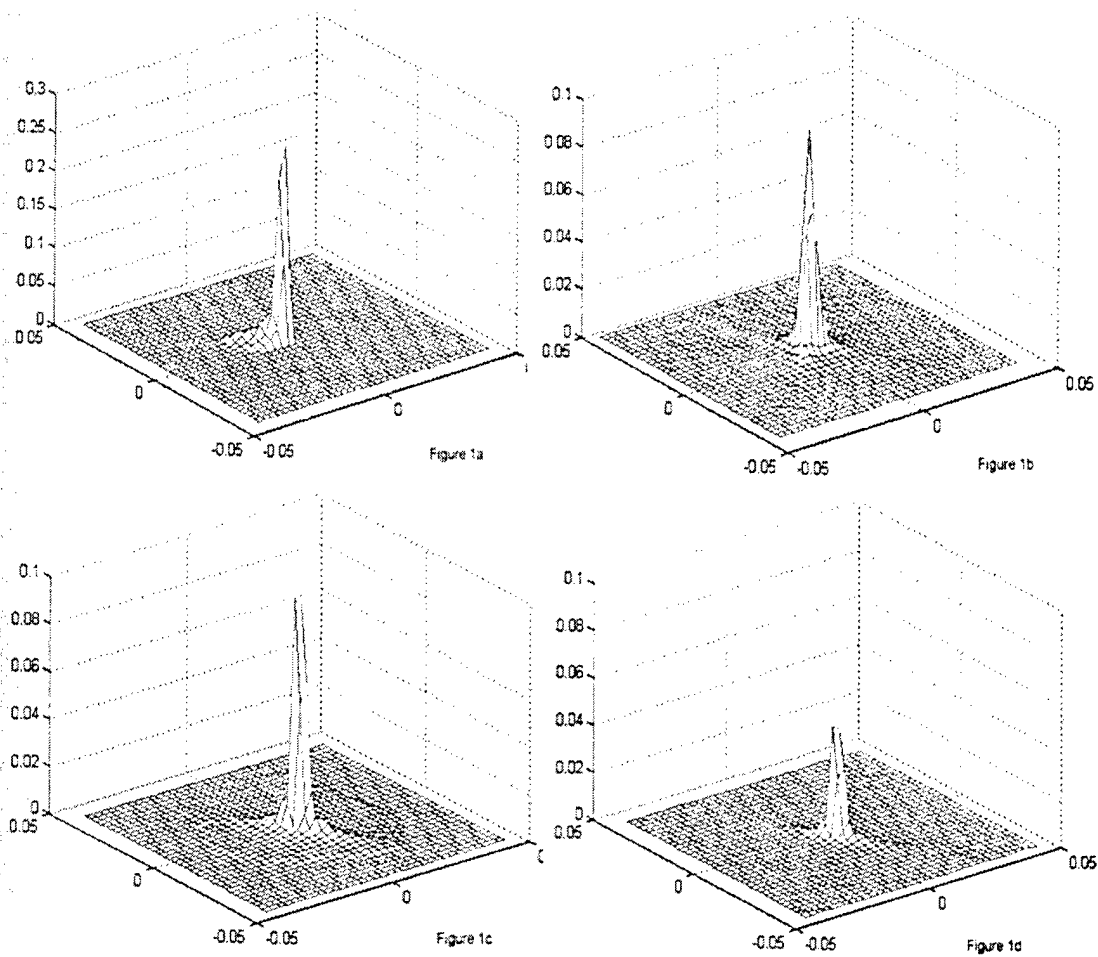
Figure 1: Normalized point spread functions of measured surfaces. The PSF of an ellipsoid (Figure 1a), apical radius of curvature 9 millimeters and pupil 4 millimeters, produces a high narrow peak, near 0.3, and very little tail, although there is slight evidence of coma seen at the base of the function. The PSF of a sphere (Figure 1b), radius of curvature 7.1 millimeters and pupil 4 millimeters, has a wider base corresponding to spherical aberration and a much lower peak, value 0.09. The bottom two panels are of a normal cornea with a 4-millimeter pupil (Figure 1c) and a 6-millimeter pupil (Figure 1d). The larger pupil results in a lower normalized PSF in Figure 1d.

The modulation transfer function (MTF) is the fourier transform of the PSF

and allows another means of understanding the optics of the corneal surface [32-

37]. Figure 2 depicts the relative MTF of the four conditions presented in Figure

1: an ellipse, a sphere, normal corneal optics with a 6-millimeter pupil and the

same cornea with a 3-millimeter pupil. It can be seen from this figure that spherical aberration causes a more rapid fall-off of the function, implying less transfer of higher frequencies. Of particular interest in the present study are the portions of the curve applicable to HCVA (30-60 c/d) and SLCT (15-25 c/d) performance.
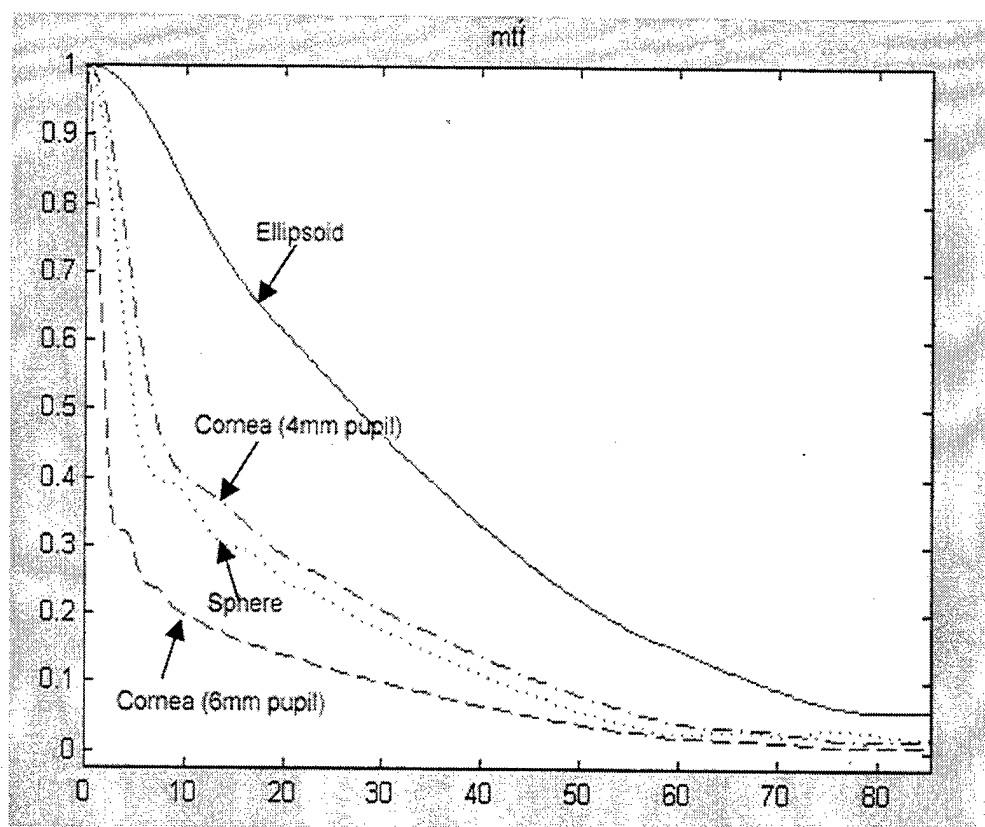
Figure 2: The relative modulation transfer functions for the four shapes depicted in Figure 1. The solid line represents the ellipsoid; the dotted line represents the sphere; the dash-dot line represents the normal cornea with a 4-millimeter pupil and the dashed line the same cornea with a 6-millimeter pupil. The sphere and normal cornea with a 4-mm pupil have very similar MTFs. The sphere produces an MTF consistent with spherical aberration and the MTF of the normal cornea with a 6-mm pupil is depressed below the level of the sphere.

4.2 Methods

4.2.1 Subjects

Forty-three refractive surgery patients served as subjects for the study. A total of 76 eyes were entered into the study. Most eyes had PRK (n=27) or PARK (n=28) in the FDA phase III trial for the NIDEK scanning laser system. Two eyes were treated using the VISX laser, one PRK and one PARK. A few representative cases of LASIK (n=15) and the intrastromal corneal ring segment (ICRS) (n=4) are included for comparison since these procedures do not produce surface haze as the surface excimer procedures do. Subjects were tested pre-operatively and 1, 3, 6, 9, 12, 18, and 24 months post-operatively according to the FDA study protocol. For the surface excimer procedures, only the preoperative and the latest examination 6 or more months post- operative are included in this study. Subjects whose corneal clarity had not returned to pre-operative levels by 6 months were excluded from the study. Two eyes were excluded using this criterion, one PRK and one PARK. Seventy-four eyes of 42 subjects were therefore included in the study.

4.2.2 Visual and Corneal Measurements

At each visit, HCVA on the Snellen acuity chart was measured after manifest refraction. Acuity was converted to logMAR as previously described (Chapter 2). Contrast sensitivity under standard luminance conditions was measured using the SLCT and recorded in logCS. The testing procedures and scoring criteria for the SLCT are presented in Chapter 2. Details of the number of

eyes studied, the mean correction and the mean change in both visual performance measures are presented in Table 1. The slight differences in HCVA and SLCT changes from those presented in Chapter 2 for the LASIK group are due to the three additional eyes evaluated in this chapter.

Table 1
Demographics for eyes included in study
Means and standard deviations

Procedure	Eyes (n)	Achieved Correction (diopters)	Change in HCVA (logMAR)	Change in SLCT (logCS)
ALL	74	6.2 (2.7)	-0.03 (0.07)	-0.19 (0.25)
PRK	27	7.8 (3.2)	-0.05 (0.07)	-0.26 (0.17)
PARK	28	5.3 (1.6)	-0.01 (0.07)	-0.09 (0.17)
LASIK	15	6.2 (1.5)	-0.08 (0.06)	-0.27 (0.43)
ICRS	4	2.2 (0.8)	-0.05 (0.05)	-0.32 (0.24)

Topography was measured using the TMS-2™ topographer (software version 1.2) by Tomey. Topographic maps were scrutinized for completeness and accuracy. Many factors affect the accuracy of corneal topography, including a poor tear layer, poor contrast of the reflected rings due to the iris, and improper focusing. Breaks in the tear layer or poor contrast of the rings disturbs the completeness of the reflected ring image causing the edge finding algorithms of the topographer to trace incomplete rings or incorrect ring locations. This will result in an inaccurate or incomplete representation of the corneal surface. This affects both the calculation of indices and the reconstruction of the corneal surface for determination of EOZ and corneal optics parameters. For these reasons, maps were verified by the ring trace during reconstruction and retaken if not considered satisfactory for analysis.

4.2.3 TMS-2™ Topographic Indices

The Klyce corneal statistics on the TMS-2 are described in Appendix B. Of the twelve corneal indices provided, six were chosen for evaluation in this study based on their purported association with vision or corneal shape. The six indices chosen were described in the Introduction. In the TMS-2 program, the "Klyce Corneal Statistics" option from the TMS-2 menu was selected and each map was displayed along with the indices. Completeness of the map was verified and the SAI, SRI, best end of the PVA range, CVP, IAI and CEI indices for each map were transferred to the spreadsheet for analysis.

4.2.4 Corneal Surface Reconstruction

The TMS-2 has numerous maps to aid in the evaluation of the cornea. A complete listing is provided at Appendix C. The data files from the TMS-2 offer an additional means of topographic analysis. The height (hit*.dat) file gives the sag in millimeters from a plane perpendicular to and centered on the videokeratographic (VKG) axis. The radius (rad*.dat) file gives the radial distance in millimeters along 256 meridians from the VKG axis to each of the 28 rings imaged by the TMS-2. Using the height and radius files for each corneal map, the surface was reconstructed using a Taylor expansion (a non-orthogonal Zernike expansion). A Matlab® program takes the data files, merges the height and radius locations, reconstructs the surface and produces a file of Taylor coefficients.

4.2.5 Determination of the Effective Optical Zone

From the surface reconstruction, the refractive power at each point in a dense sampling of the cornea was determined using a Matlab® program. At each point there is a maximum and minimum curvature. The maximum curvature values were sampled to determine the minimum or baseline value for the corneal surface. From this corneal point, the maximum curvature values were sampled and contours determined for regions containing refractive powers within one diopter of the baseline value, EOZ (area 1), and two diopters of the baseline value, EOZ (area 2). The radii of the EOZ areas were recorded millimeters.

The decentration of the EOZ was calculated with respect to the pupil center. TMS-2 provides a data file with pupil radius information with respect to the VKG axis (pup*.dat). The pupil center was calculated based on this file and the geometric center of EOZ (area 2) was determined. The distance between the EOZ center (x,y) and the pupil center (x,y) is the EOZ decentration. Both preoperative and postoperative EOZ decentrations were calculated.

4.2.6 Determination of the Point Spread Function and Modulation Transfer Function

Starting with the surface reconstruction, a Matlab® program traces 3600 parallel incoming rays as they refract through the corneal surface using Snell's law. For the purposes of this study pupil size was set to 4 millimeters. The focal plane of the surface is determined using a constrained optimization search. The computed distance from the focal plane to the front of the corneal surface

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designated as R. In order to determine and remove the remaining astigmatism, the program uses another constrained optimization search. Two parameters describing cross-cylinder as well as a sphere term are varied to maximize the focal density in one of the buckets. A virtual compensating lens with that astigmatism is then applied in order to cancel the effects of the residual cylinder components and then the final PSF is computed.

The PSF is determined by density sampling of the 2.5 μm buckets at the calculated focal distance, R. Three parameters describing the PSF were extracted, the height and volume of the peak and the radius of the tail. PSF height was normalized by dividing the height by the number of points in the PSF. PSF volume is given by the density of rays within a 2 minute of arc diameter zone centered on the PSF peak divided by the overall number of rays in the PSF. An ideal PSF width is 1. The PSF radius is the mean distance in millimeters from the center of the PSF peak that encompasses 90 percent of the points in the PSF. An ideal PSF radius is 0.

The fourier transform of the PSF provides the MTF. The MTF was averaged radially to extract scalar magnitudes as a function of the radius from the central axis. The resulting function is represented as a curve. Three parameters of the relative MTF were evaluated in this study, the area under the curve and the height of the curve at two specific frequencies corresponding to the SLCT (19 cycles per degree) and HCVA (30 cycles per degree) tests.

4.2.7 Data Analysis

The goal of this study is two-fold, to evaluate the changes in corneal topography after keratorefractive procedures and to determine how these changes relate to visual performance. First, the indices developed from corneal topography, both the embedded indices and new indices developed from surface reconstruction will be analyzed to determine whether the changes after keratorefractive surgery are significant using a paired t-test protocol. The changes will be analyzed by procedure and for the entire keratorefractive group. Second, indices will be evaluated to ascertain how well they correlate to two measures of visual performance, HCVA and the SLCT. Multivariate regression will then be used to develop the best model for each category of indices and for all indices combined.

4.3 Results

4.3.1 TMS Indices

Table 2 shows the change in the TMS-2 indices that describe corneal shape, regularity and optics. When all procedures are considered together, all indices except the SRI show a significant change postoperatively. Interestingly, the SRI decreases postoperatively for all procedures, a change that is statistically significant only for the PARK group. The change in CVP, IAI and CEI indices is statistically significant for all procedures. Note the CEI, which describes corneal eccentricity, becomes negative for the PRK, PARK and LASIK groups and becomes more positive for the ICRS group.

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Table 2
Change in mean TMS-2™ indices (standard deviation) by procedure
Note: Significant changes are presented in bold (p<0.0001)
*ICRS changes are only significant at p<0.05

	SAI		SRI		CVP		IAI		CEI	
	pre	post	pre	post	pre	post	pre	post	pre	post
ALL	**0.37**	**0.47**	0.61	0.52	**17.33**	**37.31**	**0.35**	**0.50**	**0.44**	**-0.54**
	(0.30)	(0.28)	(0.37)	(0.22)	(6.36)	(18.01)	(0.09)	(0.11)	(0.12)	(0.37)
PRK	**0.36**	**0.51**	0.55	0.57	**15.28**	**46.65**	**0.32**	**0.51**	**0.42**	**-0.70**
	(0.29)	(0.37)	(0.38)	(0.23)	(5.27)	(20.27)	(0.08)	(0.12)	(0.11)	(0.11)
PARK	0.33	0.44	**0.62**	**0.45**	**18.70**	**28.49**	**0.35**	**0.45**	**0.43**	**-0.51**
	(0.27)	(0.22)	(0.33)	(0.19)	(6.47)	(11.22)	(0.07)	(0.07)	(0.13)	(0.26)
LASIK	0.48	0.50	0.69	0.57	**18.98**	**36.98**	**0.37**	**0.51**	**0.50**	**-0.64**
	(0.36)	(0.22)	(0.46)	(0.24)	(7.07)	(18.71)	(0.14)	(0.08)	(0.10)	(0.12)
ICRS	0.44	0.36	0.67	0.45	12.13	37.13*	0.39	0.71*	0.44	0.76*
	(0.37)	0.11	(0.27)	(0.18)	(2.62)	(7.15)	(0.04)	(0.09)	(0.11)	(0.07)

In Table 3 the correlation of the TMS-2 indices to visual performance is outlined. For HCVA, a positive correlation indicates that as the index becomes more positive HCVA also becomes more positive, in other words worse. The correlation of CEI to visual performance shows that with a more positive CEI, both HCVA and SLCT are improved, HCVA shifts toward negative and SLCT towards positive values.

Table 3
Correlation, *r*, of TMS-2™ indices to visual performance measures
Note: Significant correlations are indicated in bold (p<0.001)
*SAI correlation with SLCT is statistically significant at p<0.05

	HCVA	SLCT
PVA	0.16	-0.07
SAI	0.21	-0.31*
SRI	0.20	-0.09
CVP	**0.48**	**-0.54**
IAI	**0.37**	**-0.37**
CEI	**-0.33**	**0.42**

The best correlations for both visual performance measures are found for CVP, IAI and CEI. PVA does not correlate well with either visual performance measure. Multivariate regression does not produce a better model than CVP alone.

The models for HCVA and SLCT are:

- HCVA = $-0.103 + 1.684 \times 10^{-3}$(CVP)

  ($r = 0.476$, ANOVA F = 20.268, $p < 0.001$)

- SLCT = $1.189 - 8.67 \times 10^{-3}$ (CVP)

  ($r = 0.537$, ANOVA F = 27.602, $p < 0.001$)

4.3.2 Effective Optical Zone

The radius of the one-diopter and two-diopter EOZ decreases for all procedures, while the decentration of the EOZ increases for all procedures as detailed in Table 4. Figures 3 and 4 provide a graphical representation of the changes in the two-diopter EOZ radius and decentration by procedure. None of the changes for the ICRS group are statistically significant due to the small sample size (n=4), however the change in the one-diopter EOZ is consistent with and the change in the two-diopter EOZ is less than other procedures and the change in EOZ decentration is greater than other procedures. The change in EOZ decentration is only significant for the PARK group.

Table 4
Change in mean Effective Optical Zone measures (standard deviations)
by procedure
Note: Significant changes are presented in bold (p<0.001)
*PARK change in EOZ decentration is only significant at p<0.05

	EOZ1 radius (mm)		EOZ2 radius (mm)		EOZ decentration (in mm)	
	pre	post	pre	Post	pre	post
ALL	**1.66** (0.26)	**1.43** (0.21)	**17.96** (4.81)	**12.46** (3.22)	0.36 (0.24)	0.43 (0.26)
PRK	**1.61** (0.21)	**1.38** (0.20)	**17.21** (4.72)	**11.08** (2.72)	0.39 (0.24)	0.41 (0.32)
PARK	**1.63** (0.34)	**1.44** (0.22)	**17.25** (5.44)	**12.94** (3.04)	0.32 (0.23)	0.46* (0.25)
LASIK	**1.75** (0.17)	**1.51** (0.22)	**19.92** (3.65)	**13.04** (2.82)	0.39 (0.26)	0.40 (0.15)
ICRS	1.67 (0.14)	1.43 (0.18)	18.54 (2.74)	17.57 (5.14)	0.38 (0.18)	0.53 (0.23)

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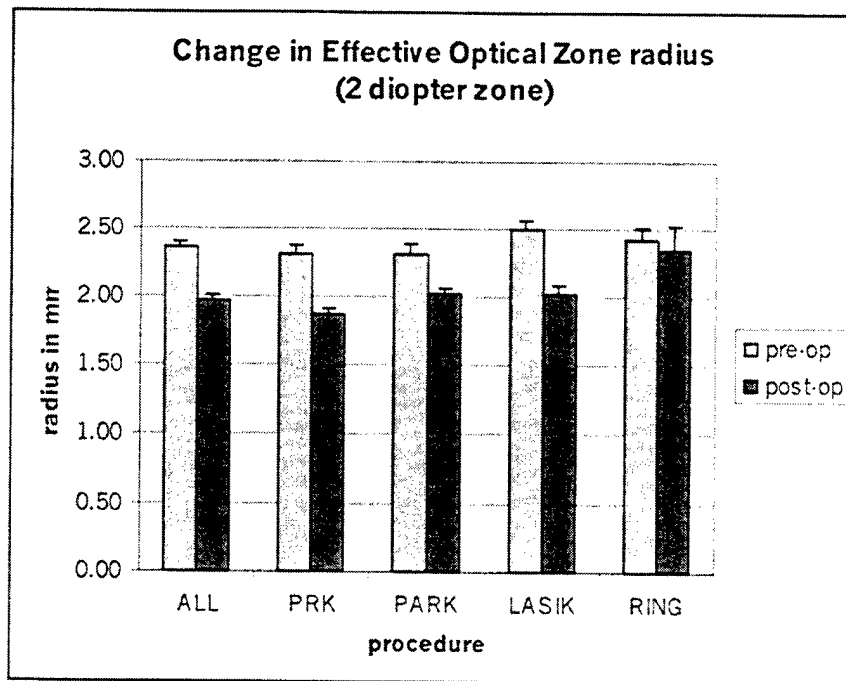
Figure 3: The mean radius of the two-diopter EOZ before and after refractive surgery. Error bars represent standard error. Note that the EOZ decreases in radius for all procedures except the ICRS.
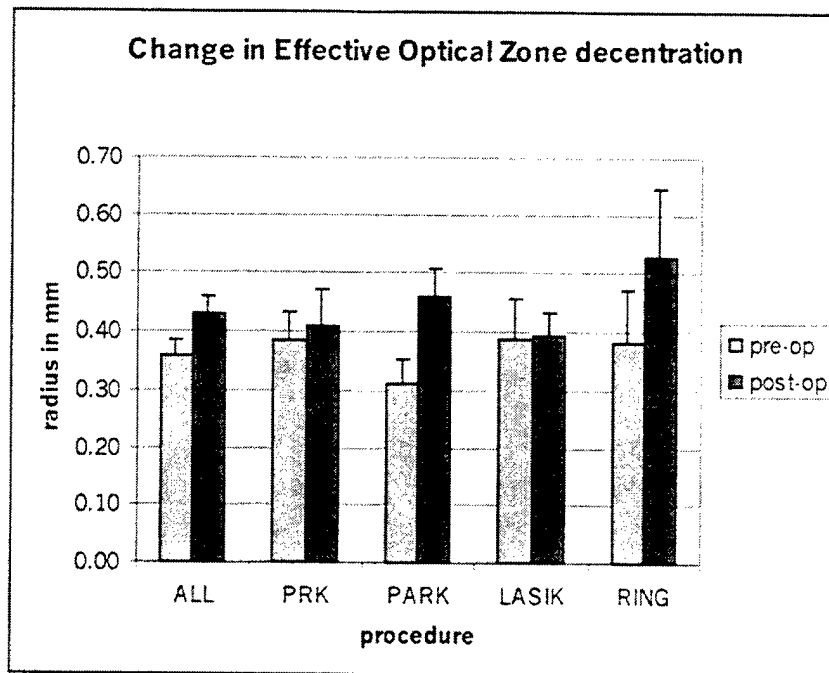
Figure 4: Pre- and postoperative EOZ decentration is plotted for all procedures. Prior to keratorefractive procedures, the EOZ of normal corneas is decentered with respect to the pupil center. The greatest increase in decentration postoperatively occurs for PARK and ICRS procedures.

Table 5 shows the correlations of EOZ parameters to the visual performance measures. The two EOZs evaluated are correlated ($r = 0.88$) and the correlations for the one-diopter and two-diopter zones to HCVA and SLCT are similar, therefore subsequent analysis will only include the two-diopter EOZ.

Table 5
Correlation, r, of the Effective Optical Zone to visual performance measures
Note: Significant correlations are presented in bold (p<0.01)
*EOZ correlations to HCVA are significant at p=0.02

	HCVA	SLCT
EOZ (1 diopter)	-0.23*	0.32
EOZ (2 diopter)	-0.23*	0.31
EOZ decentration	0.24*	-0.28

Combining the EOZ radius and decentration parameters in a multivariate regression improves the model for both visual performance measures. The models for HCVA and SLCT are:

- HCVA = $-2.73 \times 10^{-2} - 3.2 \times 10^{-3}$(EOZ2) $+ 6.73 \times 10^{-2}$(EOZ dec)

  ($r = 0.33$, ANOVA F = 4.25, p = 0.18)

- SLCT = $0.756 + 1.948 \times 10^{-2}$(EOZ2) -0.354(EOZ dec)

  ($r = 0.414$, ANOVA F = 6.910, p = 0.002)

4.3.3 Point spread function and modulation transfer function

Table 6 shows measures of the three parameters describing the PSF and how they change postoperatively for each procedure. All changes are statistically significant at p<0.001 except for the ICRS procedure where none of the changes

were significant. PSF height and volume parameters both decrease by 50%

across the remaining procedures, while PSF radius doubles.

Table 6
Change in mean Point Spread Function (standard deviations) by procedure
Note: Significant changes are presented in bold (p<0.0001)

	PSF height		PSF volume		PSF radius	
	pre	post	pre	post	pre	post
ALL	**0.250** (0.095)	**0.118** (0.063)	**0.526** (0.145)	**0.281** (0.129)	**0.032** (0.014)	**0.068** (0.038)
PRK	**0.247** (0.089)	**0.105** (0.061)	**0.516** (0.137)	**0.262** (0.145)	**0.033** (0.013)	**0.074** (0.051)
PARK	**0.255** (0.106)	**0.132** (0.071)	**0.523** (0.149)	**0.298** (0.125)	**0.034** (0.018)	**0.062** (0.025)
LASIK	**0.247** (0.075)	**0.114** (0.054)	**0.549** (0.139)	**0.274** (0.116)	**0.029** (0.010)	**0.068** (0.036)
ICRS	0.183 (0.043)	0.132 (0.046)	0.441 (0.107)	0.322 (0.110)	0.026 (0.004)	0.067 (0.026)

Figure 5 provides an example the PSF of one cornea preoperatively and

twelve months postoperatively. The PSF parameters for this cornea are equal to

the means of all three measures for the overall group (ALL).
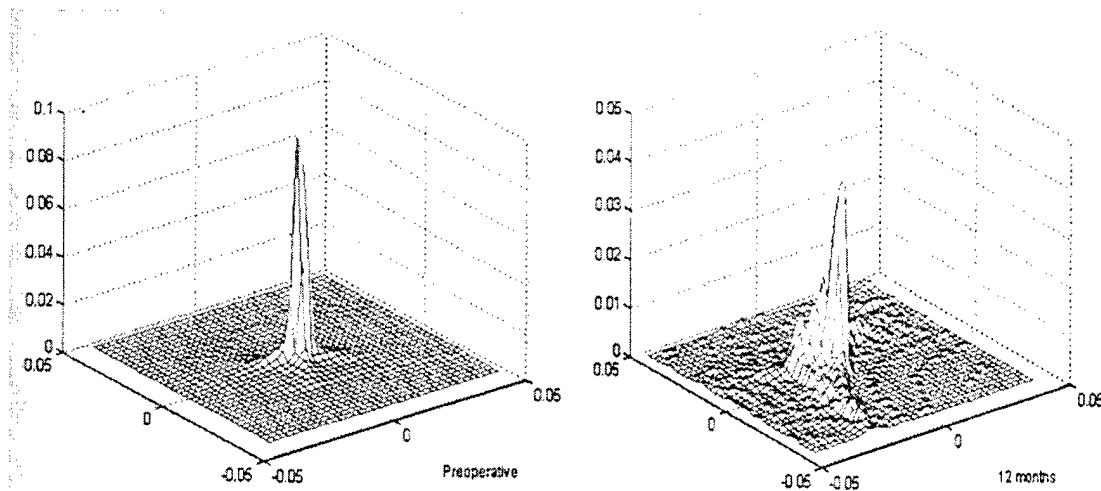
Figure 5: The PSF of a typical cornea pre- and 12 months postoperatively. The achieved correction after PRK was a reduction of 5.37 diopters of myopia. The PSF height dropped from a preoperative value of 0.1 to 0.4 postoperatively (note the difference in scales for the two panels). The decrease in volume of the peak (absolute number of points falling within a 2 minute of arc diameter) and the increase in points falling in the tail region of the PSF is also visible in the graphs.

The changes in MTF parameters by procedure are detailed in Table 7. All changes are statistically significant at p<0.0001 except for the ICRS procedure where none of the changes were significant. MTF area decreases approximately 33% across all procedures, while the height of the relative MTF function at both 19 and 30 cycles per degree decreases 50% for all except the ICRS procedure.

Table 7
Change in mean Modulation Transfer Function measures (standard deviations) by procedure
Note: Significant changes are presented in bold (p<0.0001)

	MTF area		MTF at 19c/d		MTF at 30 c/d	
	pre	post	pre	post	pre	post
ALL	**19.18**	**13.06**	**0.260**	**0.127**	**0.166**	**0.078**
	(3.08)	(3.46)	(0.096)	(0.062)	(0.068)	(0.041)
PRK	**18.79**	**12.72**	**0.257**	**0.116**	**0.162**	**0.071**
	(3.03)	(4.17)	(0.092)	(0.059)	(0.064)	(0.037)
PARK	**19.24**	**13.61**	**0.264**	**0.140**	**0.170**	**0.087**
	(3.03)	(3.20)	(0.100)	(0.071)	(0.072)	(0.048)
LASIK	**19.30**	**12.74**	**0.256**	**0.121**	**0.167**	**0.073**
	(3.05)	(2.63)	(0.093)	(0.051)	(0.059)	(0.030)
ICRS	18.89	12.67	0.206	0.136	0.116	0.086
	(2.47)	(3.27)	(0.039)	(0.051)	(0.026)	(0.041)

Figure 6 is a plot of the mean relative MTF's for the preoperative data and each of the four procedures evaluated. There is no significant difference between the four procedures in terms of relative MTF shape, however all four differ significantly from the preoperative plot.

MTF after refractive surgery
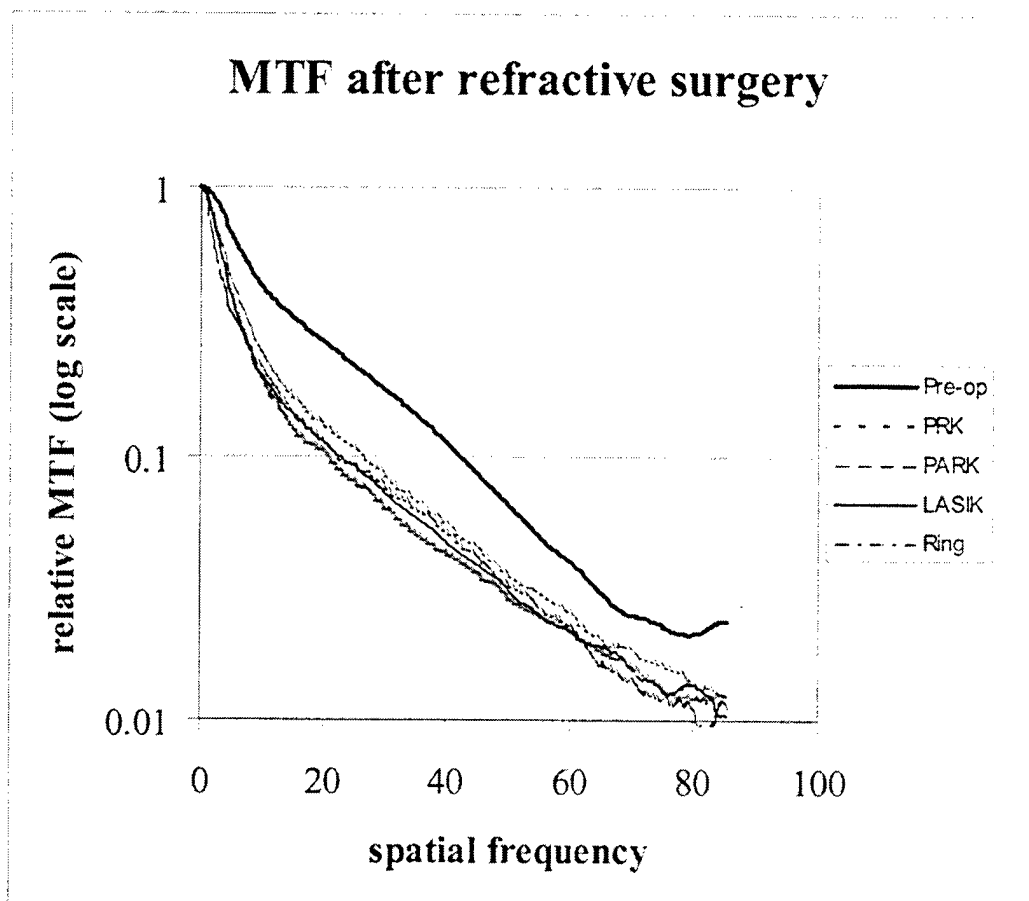
Figure 6: The mean relative MTF for each procedure is plotted with the mean relative MTF for the preoperative corneas on a semilog plot. The postoperative MTF's all fall below the preoperative MTF with the PRK MTF lowest and the PARK MTF highest, especially between 10 and 30 cycles per degree.

The correlations between the PSF and MTF parameters and visual

performance measures are given in Table 8. All correlations are significant at

$p < 0.001$.

Table 8
Correlation, *r*, of the PSF and MTF parameters to visual performance measures
Note: Significant correlations are presented in bold (p<0.001)

	HCVA	SLCT
PSF height	**-0.40**	**0.43**
PSF volume	**-0.41**	**0.45**
PSF radius	**0.49**	**-0.47**
MTF area	**-0.43**	**0.47**
MTF at 19 c/d	**-0.37**	**0.41**
MTF at 30 c/d	**-0.36**	**0.37**

Multivariate regression of the six indices produces the following models:

- HCVA = $-5.58 \times 10^{-2} - 0.656$(PSF height) $+ 0.772$(MTF 30) $+ 0.588$(PSF rad)

  ($r = 0.513$, ANOVA F = 7.989, p < 0.001)

- SLCT = $0.981 + 3.598$ (PSF height) $- 2.883$(PSF rad) $- 2.917$(MTF 19)

  ($r = 0.519$, ANOVA F = 8.103, p < 0.001)

4.4 Discussion

4.4.1 Keratorefractive procedures and topographic indices

The keratorefractive procedures evaluated in this study are all designed to reduce myopia by decreasing corneal curvature. The change is not always easy to discern from the corneal maps produced by corneal topographers [38], which has let to the need to evaluate other tools to characterize the shape and optics of the cornea. The corneal indices provided by the TMS-2 topographer were all affected by the keratorefractive procedures to varying degrees. The greatest change from preoperative values were for the CVP, IAI and CEI indices. CVP increases due to the greater range of powers over the corneal surface postoperatively. For any procedure that produces a transition zone between the

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altered corneal area and the original corneal curvature peripherally, CVP is expected to increase. The change in IAI points to an increase in localized irregular astigmatism and therefore a decrease in the surface quality of the cornea. CEI results show a shift from a prolate corneal surface to an oblate surface for eyes after PRK, PARK and LASIK. The ICRS eyes experienced an increase in the CEI index, demonstrating an increase in positive eccentricity.

The SAI and SRI were not significantly altered by the keratorefractive procedures, in fact SRI values decreased postoperatively across all procedures except PRK. This is a reflection of the quality of the ablation in surface excimer procedures, the smoothness of the flap in LASIK and the evenness of the corneal response to the implantation of the ICRS. When the area of refractive correction is well-centered and smooth, the SAI, which measures differences across corresponding points of the cornea, and the SRI, which measures the regularity of power along each meridian of the cornea, remain within normal limits.

The radius of the two-diopter EOZ decreases after all procedures except the ICRS, while the increase in EOZ decentration is only significant after PARK with a comparable change measured for the ICRS eyes. Since the EOZ is measured in terms of radius, the shape of the EOZ is not considered in the analysis. To illustrate the potential impact of this factor, Figure 7 presents examples the EOZ's of a cornea after PRK and another cornea after ICRS.
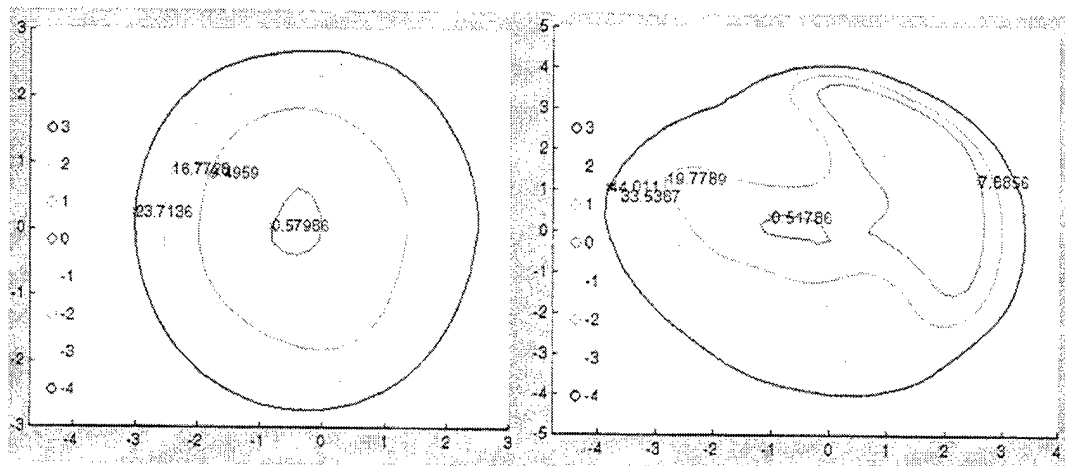
Figure 7: Comparison of EOZ configurations for two corneas, PRK (left panel) and ICRS (right panel). The two-diopter zone, represented by the light gray line, is smaller for the PRK eye (2.31 mm radius) than the ICRS eye (3.25 mm radius), however the shape is significantly more irregular for the ICRS eye.

The indices describing the image-forming properties of the cornea through evaluation of the PSF and MTF also show significant changes after keratorefractive procedures. As shown in Table 6 and the example in Figure 5, the peak of the PSF decreases in height and volume, while the number of rays falling outside the peak increases resulting in an increase in the radius of the PSF tail. The changes after keratorefractive procedures are not as dramatic as that demonstrated by the PSF of a spherical surface shown in Figure 1b, however they are measurable and potentially significant to vision. Given the impact on the PSF, the MTF results are predictable, decreased area under the MTF function and decreased height of the function at the two spatial frequencies evaluated, 19 and 30 cycles per degree.

All PSF and MTF parameters showed statistically significant changes for all procedures except the ICRS. This is due to the small sample size of the ICRS

group (n=4) and the lower preoperative levels for the PSF and MTF parameters. The postoperative levels for the ICRS group were slightly better than the overall group means (see Tables 6 and 7), possibly due to the lower amount of refractive correction achieved with this procedure (see Table 1). The net result was a lower absolute amount of change for the ICRS group.

4.4.2 Corneal topographic changes and visual performance

Despite the number of indices with statistically significant differences from preoperative levels, the relationship of the indices evaluated to visual performance, as measured in this study, is less solid. The TMS-2 index specifically designed to provide an indication of potential visual acuity (PVA) did not correlate well with either visual performance measure (HCVA, $r = 0.16$; SLCT, $r = -0.07$). The SAI and SRI indices were likewise poorly correlated to visual performance (see Table 3). Both preoperative and postoperative measures were included in this analysis and, coupled with the lack of extremely distorted corneas, may explain the significantly lower correlations than those found in the two previously cited studies.

The best index in each grouping was the TMS-2 CVP index, the EOZ radius and the PSF radius. This indicates that visual performance is affected by the range of powers of the corneal surface, the size of a consistent refractive power area and the negative influence of rays falling outside the central PSF peak. Using multivariate regression to attempt to strengthen the models, the best correlation with HCVA was achieved using the PSF height, PSF radius and the

height of the MTF function at 30 cycles per degree ($r = 0.513$). For SLCT, the best model was achieved using the CVP ($r = 0.537$). Across all the models, the correlations are generally better for SLCT than HCVA, indicating that SLCT performance is perhaps more sensitive to the changes in corneal shape than HCVA.

4.5 Conclusions

The key to connecting corneal changes with visual performance changes is in the ability to accurately map and analyze the corneal surface and the ability to very precisely measure changes in visual performance. From the results in Chapter 2 and the results of this study, there are solid indications that the SLCT is a sensitive measure of visual performance after keratorefractive surgery and that corneal topography can provide significant information about vision and the effects of corneal modifying procedures.

An ideal topographic index would be one that is sensitive to corneal changes, predictive of visual performance, and meaningful to the practitioner. Many of the indices evaluated in this study were sensitive to corneal change and clearly showed the effects of the various procedures on corneal shape and optics. The ability to use this information to predict visual performance will require two major improvements in the present technique, consideration of optical factors beyond the corneal surface and further refinement of visual performance measures that truly reflect real-world vision. The TMS-2 and EOZ indices may be strengthened by only including the area of the cornea directly anterior to the entrance pupil.

Ray tracing which includes the posterior corneal surface and the crystalline lens would improve the PSF and MTF indices. Including pupil size corresponding to the lighting conditions of each test would also refine the PSF and MTF information.

Studies of the optics of the eye after refractive surgery have shown significant changes in corneal optics and the wavefront aberrations of the eye [39-42], yet few studies have looked at how these correspond to vision [43, 44]. As techniques for correcting refractive error start to include more refractive implants and other yet-to-be developed techniques, the need to look beyond corneal shape changes and improve functional visual assessment is paramount.

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Chapter 5

Keratorefractive Surgery: More Perspectives

5.1 Introduction

This chapter takes a look at refractive surgery from a different perspective from the rest of the dissertation. Keratorefractive procedures are elective, correcting refractive error for individuals who generally had adequate vision using other corrective modalities prior to the procedure. Success, therefore, takes on a new meaning. Instead of being driven by an improvement of vision through the removal of an opacity, such as a cataract, it is achieved when the patient is more satisfied with his or her vision than they were prior to the procedure. Other factors contribute, as well. Unlike other elective procedures, such as plastic surgery, the possible deficits in vision due to intraoperative or postoperative complications are potentially life altering. Long term effects for the most recent procedures are not known. Then again, long term effects of contact lens wear are certainly known and have been found to negatively impact ocular health and corneal clarity.

For individuals with significant refractive error, the various modes of refractive correction are all a compromise. The question of whether refractive surgery is the best option among those available has to be determined by the individual. Visual performance measures and corneal optics are of very little

interest to the patient. What the patient desires is the ability to see the alarm clock without having to reach for his or her glasses, to donate their thick glasses to charity and to free their corneas from irritating contact lenses. Vision will be undeniably different from the preoperative state and these differences, whether subtle or pronounced, must be tolerable to the patient. As the newness of the lifestyle change wears off, other aspects of their new visual system become apparent. For some individuals the changes are barely noticeable, for others they are significant. This is the realm of subjective response, where for one person the change is an affliction while for another person it is a blessing.

In this chapter, I sought to put together the reasons why patients I have come in contact with chose refractive surgery, what it was like going through the procedure and immediately after the procedure, how they rated any symptoms they experienced, and what happens when things go wrong. Given the results presented throughout this dissertation, in terms of corneal changes and visual performance, and the input from many patients in the study and in general clinic, the final part of this chapter is geared toward the future. The techniques for correcting refractive error may change, however the standards defining a successful outcome need to be set adequately high to ensure development of the best techniques and the preservation of sight.

5.2 In their own words

5.2.1 Why refractive surgery?

I assisted in the corneal topographic evaluation of a now hyperopic patient who had undergone RK while in Mexico. She had failed to bring an adequate supply of contact lenses and solutions while on vacation and decided to visit a local optical shop for replacement. The doctor convinced her that she would be better off getting surgery than new contact lenses, she now has both. This, of course, is a very unusual reason for getting refractive surgery. More typical reasons include putting aside the inconvenience of glasses or contacts and gaining unencumbered vision for sports.

Currently, patients who choose laser refractive surgery are older than those who choose contact lenses. A study by Naroo, et al (1999) found that patients presenting to the clinic for PRK (mean age 36.5 ± 9.5 years) were significantly older than those presenting to the clinic for first time contact lens wear (mean age 26.3 ± 8.4 years) [1]. Annie, who had laser in-situ keratomileusis (LASIK) one year ago, states she first considered the option "when (she) got to the bifocal stage. It took (her) about one and a half years to make the decision because (she) wanted to be sure it was safe and the cost was not easy to justify ($4600)." She is a typical refractive surgery patient, in her early 40's, educated and informed, has access to disposable income, and has become dissatisfied with her other options.

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5.2.2 The experience

The best description of what it is like to go through a surface excimer procedure has to come from an individual who experienced it. Caroline is a 62-year-old caucasian, currently working as a paralegal. She had PARK to correct about three diopters of myopia and one and a half diopters of astigmatism in both eyes. The following are excerpts from Caroline's notes about going through the PARK procedure and the days following the procedure.

Day 1 - Friday

First of all, I was glad that I had the opportunity to read the book, "Beyond Glasses" which describes the various procedures and give an idea of what to expect. However, there is nothing describing the removal of the epithelium before laser surgery can be done. This is just like swimming under water with your eyes open.

The procedure is once again explained as you are going in. The technician adjusts the chair. You lay flat on a chair similar to a dentist's chair. The eye being worked on is marked with a red dot above the eyebrow. The other eye is covered but you are instructed not to close it during the procedure. You want to lie perfectly still so be sure you are comfortable and relaxed. Listen carefully to the instructions. Keep focused. The eye is kept open with a speculum. This was a bit difficult to get on my eye but the third try worked. You focus on a green light but there is also a red light. The technician and ophthalmologist can see how you are doing and talk you through as they proceed. First they line up everything and check the calibration. They turn on the machine which sounds like a vacuum cleaner. I did not smell anything particular nor pay attention to the popping sound which they had told me could be heard as the laser performs.

A lens is placed on the cornea after surgery to protect it. This lens has to be loose but not too loose as the cornea swells later. Adjusting the lens took some time. It appeared to be a probe-like instrument with a soft end like a Q-tip. You can see this. Then you sit up and wait 5 minutes before the surgeon checks everything to make sure the lens is in right.Then the surgeon gives you instructions as to medication. They include antibiotics, pain killer, steroids, and artificial tears. You should get your pain pills beforehand—usually vicodin.

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Luckily it was a cloudy day as light is a real problem. Also, luckily I was able to close (wink) my right eye which was the most comfortable position, although I could see. Resting, sleeping and taking drops regularly the first day was the best. The eye waters a lot yet is very dry and needs refresh eye artificial tears as often as possible. Another very helpful item is soft gel-like ice bag or frozen vegetables (peas, corn). A cold compress helps with the swelling.

Watching TV in the afternoon was not a problem but when the sun went down the TV took on a sharp light effect and was very troublesome. I ended up listening to the TV while facing the opposite direction.

I took vicodin before going to bed. They stressed not to wait for pain, but to take ibuprofen at regular intervals. I had the ice pack and water at my bedside. Also a box of kleenex. Having slept a lot during the day, it was hard to sleep through the night. The eyelid was sticky once when I woke up so I took a washcloth and ran hot water on it and then held it to the closed eye. I put in artificial tears 3 times that night.

Day 2-Saturday

Around 6 am I felt great—no problem. But that did not last long so I put in antibiotics at 7. As you get up and walk around, thing start to ache a bit.

We had to go back to UCSF at 10:30 am. The doctor said 8mm of epithelium had been removed and it had grown back to 5mm diameter already. The epithelium was also growing flat, not curled. I was instructed to keep it moist.

I had two episodes of a very uncomfortable feeling in the eye. Once at the optician where we got the glasses fixed around noon Saturday and again around 4 pm after a nap. The pain drops, closing the eyes, dark glasses, the ice pack and rest finally alleviated the discomfort. Really cannot call it pain.

Went for a walk at night and found no glasses was better than glasses. Whenever I tried the glasses, even with the right lens removed, I could not focus. I was able to watch TV better on the second night. Went to bed at 10 pm and slept through until 3:30. That was better.

Day 3-Sunday

Again, in the morning I had no discomfort upon getting up. However, after a shower and bending over caused some problems which were relieved by medication and closing my eyes. This went more uneventful except the sun light was a big problem despite sunglasses.

Dr. Corina checks the eye with the slit lamp at U.C. Berkeley Sunday afternoon. She believed the epithelium had covered to 3mm; however, she saw a bit of curl. It should not curl, so I am making sure I use artificial tears regularly. In the evening I experienced some discomfort, but I had not rested that day.

Day 4-Monday

We went to UCSF on Monday but the lights in the dark were a big problem—squares with a circle in the middle and many points to all corners and sides.

The ophthalmologist checked the eye and now the epithelium had healed to within a minute slit. He left the lens in and I need to return on Tuesday. I drove to San Jose wearing sunglasses in a light rain and usually keeping my right eye closed. I did manage it. Parked the car and put in eye drops and then went to work. I was able to work until 3:45, but reading as I typed was difficult. I could read the screen but not the text on the desk. It was easier to work without any glasses—cannot get the eyes to focus even though one has plain glass.

My throat was constantly raw as my nose ran so much and the medication put into the eyes bothered the whole system. I feel like I am not part of this world, but have stepped away. It is amazing how when you put drops in your eyes, you can taste or feel the drip in your throat. But I learned if you hold the corner of your eye tight, you can prevent the drip.

Day 5-Tuesday

Tuesday I worked from 7:30 to 11 and then went to UCSF. The eye was very irritated and as it turned out, the lens had moved way up under the eyelid. The healing was complete, so no more lens. Driving during the day is okay with dark glasses, but at night it is still difficult to adjust to one clear glass and the other in bifocals. I returned to work but left at 4:30 to drive during daylight. That night I could watch TV without glasses. If I need to read something on the screen, I close my left eye.

Caroline's vision stabilized approximately one month after the procedure for each eye. Her ending refraction was plano for the right eye and +0.50 diopter sphere for the left eye. She was a rare patient in that she did not develop haze in the postoperative period; in fact her objective haze measurements showed a decrease in Peak haze at the one-month examination.

LASIK is a procedure that conforms more to the mindset of the typical American who has very little time to wait for results and cannot be bothered by any inconveniences. After LASIK the bandage effect of the corneal flap reduces the likelihood of pain and since the epithelium remains intact, visual results are much more immediate. Annie's description of her experience validates these points.

> My husband drove me to the clinic the morning of the surgery. The procedure didn't last long, about 20 minutes total. There wasn't any discomfort immediately after the procedure, but on the way home I was very photophobic and my eyes burned to the point of it being painful. This really scared me. My doctor was thorough and had made sure I understood the LASIK procedure, but no one had mentioned "pain." I was told I could experience some discomfort for 3-4 hours after surgery, but for me this was more than discomfort.
> I continue to rest and felt uncertain of what was to come. I was surprised how tired I was. I think it was because I had more anxiety about having the procedure than I realized.
> About three hours later the burning stopped. I was able to open my eyes without the earlier photophobia and, much to my relief, I could see! During the rest of the day my vision continued to improve. The following morning I was so surprised when I awoke and could read the clock across the room. It was a strange sensation.

Annie had experienced pain, however the time course of pain and healing was greatly reduced when compared to the Caroline's account after PARK. She had also opted to have both eyes corrected at the same time, which eliminated

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any symptoms stemming from anisometropia in the waiting period between procedures.

5.2.3 One year later

A study by El-Maghraby, et al (1999) found that for patients who had received PRK in one eye and LASIK in the other, one year after the procedure the LASIK eye was preferred 2 to 1 and by two years postoperative there was no preference [2]. At the one-year postoperative point, Caroline and Annie were also quite satisfied with their outcomes. Caroline's greatest challenge came from having to remember to keep reading glasses close at hand since now "reading glasses are necessary for any reading such as books, newspapers, the phone book, mail, etc. Simple over-the-counter reading glasses have proven adequate, but remembering to always have one on hand is a problem. Going to the grocery store (or any shopping for that matter requiring the reading of labels and price tags), for instance, requires taking reading glasses along." Presbyopia was not such a pronounced problem prior to the procedure, since she had worn her glasses full-time and they included a bifocal. The only other symptom she mentions has to do with low luminance conditions. "Night vision is generally not a problem except at dusk when occasionally things are not as clear as during the day or later at night."

Due to an undercorrection in one eye, Annie gained the unexpected advantage of monovision. Shortly after the procedure she had noticed that the distance vision in her right eye was not as clear as her left eye. At first this was a

concern, however she soon discovered a phenomenon called adaptation. "It only took about three weeks for me to adjust to the difference in my sight. Moreover, I discovered I could read without glasses. I had, though I hadn't requested it, ended up with a mild monovision. I had tried monovision with contacts and hated it, but somehow this was different- it was great!" Her need for glasses was not completely gone, however. "I do, however, wear glasses for night driving, something I had problems with before LASIK. I also like to wear them when going to a play or a movie, but day to day I rarely notice the weakness in my right eye."

5.3 Symptoms and Satisfaction

5.3.1 A survey

There have been many reports of symptoms and satisfaction after refractive procedures, however as each new procedure and improvements to existing procedures emerge, the applicability of earlier reports diminishes. The most commonly reported symptoms after RK and PRK have been night vision disturbances, haloes and glare. There are at present very few reports of symptoms after LASIK since most efforts are focusing on refractive outcome and complications. The purpose of the present study was to survey the patients whose visual performance and corneal topographic changes were evaluated in the studies within this dissertation and to compare their ratings of symptoms with

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an age-matched group of normals. Matching symptoms and satisfaction with visual performance measures will not be addressed in this study, however.

5.3.2 Survey methods

Twenty-five refractive surgery patients completed a survey of visual symptoms and satisfaction at least three months after both eyes had been corrected. The mean postoperative time was 5.5 months, range 3 to 12 months. A group of thirty-eight normals completed a reduced survey that included the same visual symptom questions. The normal group consisted of a random sample of optometry clinic patients and students at the University of California at Berkeley and office workers at two different companies. Table 1 details the demographics of the two groups and visual demands on the job. The type of occupation of the individual, number of hours per day working on the computer and number of hours per day reading determined the visual demand rating on the job. The visual demand was rated higher for the normal group than for the postoperative group.

Table 1
Group Demographics

	Normals	Post-op
Number of subjects	38	25
M/F (%)	64% male/ 36% female	52% male/ 48% female
Age:		
≤ 40 years old (%)	58%	64%
> 40 years old (%)	42%	36%
Visual demand on job:		
High (%)	63%	28%
Medium (%)	27%	60%
Low (%)	10%	12%

The surveys covered visual demand on the job, visual symptoms such as haloes, glare, ghost images and dry eye and ease of daytime and nighttime driving. The symptoms were rated in terms of their level after work and on days off. For the refractive surgery group additional questions were asked evaluating the level of satisfaction with the outcome of the procedure.

5.3.3 Results and discussion

Table 2 gives a summary of the use of for the two groups. The first thing to notice is that only 50% of the postoperative group compared to 35% of the normal group are not wearing any type of refractive correction. The normal group is also more likely to wear glasses to correct their refractive error, as evidenced by the difference in full-time glasses and part-time distance correction worn, assuming that a part-time distance correction is more likely to be glasses than contact lenses. The percentage of people wearing reading glasses on a part-time basis is equivalent for the two groups.

Table 2
Use of Eyewear on the Job

	Normals	Post-op
Use of eyewear:		
Full-time Glasses only (%)	26%	0%
Full-time Contacts only (%)	3%	4%
Full-time glasses or contacts (%)	0%	31%
Part-time Distance (%)	19%	0%
Part-time Near (%)	16%	15%
No correction (%)	35%	50%

Table 3 shows the mean and standard deviations for the ratings for each of eight visual symptoms. Each symptom was rated on a scale of one to five, with

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one indicating "very often," three indicating "sometimes," and five indicating "never."

Table 3
Comparison of symptom ratings
Note: significant differences between groups are indicated in bold

Problems with:	After work		Days off	
	Normal	Post-op	Normal	Post-op
Glare	4.30 (1.0)	3.80 (1.3)	**4.49 (0.9)**	3.72 (1.4)
Halos	4.27 (1.2)	3.96 (1.2)	**4.65 (0.6)**	4.00 (1.3)
Day driving	4.62 (0.7)	4.76 (0.5)	4.73 (0.5)	4.80 (0.5)
Night driving	4.14 (1.0)	3.88 (1.1)	**4.54 (0.7)**	3.80 (1.3)
Dry eye	3.70 (1.3)	3.96 (1.1)	4.30 (1.0)	3.88 (1.2)
Reading	4.14 (1.0)	4.24 (1.0)	4.51 (0.6)	4.36 (1.0)
Ghost images	4.68 (0.6)	4.76 (0.6)	4.78 (0.5)	4.92 (0.3)
Eyestrain	**3.38 (1.2)**	**4.20 (0.9)**	4.19 (0.7)	4.40 (0.9)

The symptom ratings are not statistically significantly different for the two groups for the period right after work except for the symptom of eyestrain, which is rated as less problematic for the refractive surgery group (t-test 3.13, p=0.002). More differences between the groups are seen for the symptoms during days off, specifically for the symptoms of glare, halos and night driving. All of these symptoms were rated more problematic by the postoperative group (glare t-test = 2.7, p=0.009; halos t-test = 2.5, p=0.01; night driving t-test = 2.9, p=0.006).

One of the main differences between the ratings of symptoms of the two groups is that the normal group rated visual symptoms worse after work than on days off and the postoperative group rating the visual symptoms almost identical for the two timeframes. This may be due to the higher visual demand of the normal group and indicates that this factor should be considered in future comparisons. If one only considers the ratings during the days off timeframe,

then the symptoms reported by the postoperative group are in keeping with previous research findings.

Looking more specifically at the symptoms of glare, halos and night driving problems, the number of subjects rating each symptom as a one, "very often," is as follows:

- Glare – 3 of 25 postoperative and 1 of 38 normal subjects

- Halos – 4 of 25 postoperative and 0 of 38 normal subjects

- Night driving – 6 of 25 postoperative and 0 of 38 normal subjects

These numbers seem to show the higher level of visual complaints among the refractive surgery group. One factor that is not addressed in evaluation of visual symptoms after refractive surgery is the fact that patients are often tuned in to the kinds of postoperative symptoms evaluated through preoperative counseling and questionnaires and may, therefore, be more likely to make note of symptoms.

5.3.4 Satisfaction

With corneal, visual performance and symptomatic changes documented for the postoperative group, a few patients would be expected to express regrets about their decision to have refractive surgery. This was not the case. 92% (23 subjects) indicated that their quality of life had improved, one subject stated it had not changed and one subject stated that it had gotten worse, yet 100% of the patients surveyed indicated they would choose surgery again. As far as reasons for satisfaction with the outcome, convenience and vision in general were rated highest and looking better was at the bottom of the list.

5.5 Outcomes assessment

5.5.1 Visual performance and ocular integrity

Other than the accuracy of the refractive correction, visual acuity and complications standards already recommended by the FDA, two other areas should be included in the assessment of refractive surgery outcomes: visual performance and ocular integrity. Although maintenance of high contrast acuity is a reasonable goal, it is not necessarily the most sensitive measure of visual performance, as has been shown in this dissertation. Maintenance or improvement of contrast sensitivity across the entire function may be a difficult standard to attain; however for the preservation of sight it is a worthwhile goal. Ocular integrity standards should include maintaining or improving clarity of the media, mechanical and physiological stability, and minimizing the aberrations of the visual system. Certainly changes in ocular integrity can affect visual performance, an indication that the recommended standards are interrelated.

With these goals in mind, the following factors should be considered in the evaluation of any procedure intended to improve the refractive status of the eye:

- Visual performance under standard and low luminance conditions to allow for the impact of physiological pupil dilation
  - ✓ High contrast visual acuity
  - ✓ Contrast sensitivity (including high end of CSF using Bailey-Lovie Low Contrast chart or the Rabin Small Letter Contrast Test)

- Measure of ocular clarity, using instruments such as opacity meters or haze meters

- Wavefront aberration of the eye

  ✓ Shack-Hartmann device to measure aberration of the eye

  ✓ Corneal and other surface topographic measures to determine change in aberration structure of individual surfaces

- Mechanical stability of the eye

  ✓ Studies of resistance to trauma (eye bank and animal studies)

  ✓ Studies of failed cases

- Physiological stability of the eye

  ✓ Corneal and anterior segment evaluation (e.g. pachymetry, endothelial evaluation, intraocular pressure, crystalline lens thickness)

  ✓ Posterior segment evaluation

5.5.2 Progress without risk?

Fifty years ago Dr. Harold Ridley implanted the first intraocular lens (IOL) [3] [4]. The ending refraction was −14.00 diopters. Although the IOL was not popular among his ophthalmological peers he pressed forward. During the next four years Dr. Ridley implanted 1000 more eyes with improving results. Without patients willing to have IOL's implanted and without eye care practitioners concerned about constantly improving the technique, cataracts would still be couched. In the same vein, if there were not individuals willing to take a risk to

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reduce their reliance on glasses or contacts, refractive surgery would also be an unknown entity.

Since 1949 there have been significant advances in medical technology. This has allowed advances in current refractive surgery techniques to progress at an incredible rate. As each new technique emerges, new challenges exist for eye care practitioners and vision scientists to ensure the technique meets the demands of the patient, improving quality of vision and quality of life, and that it withstands the test of time. Outcomes evaluation feeding back into the development of new technologies will help to drive future improvements.

Chapter 5 References

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Appendix A
Subject data

Subj	M/F	Age	Date	Eye	Visit	Tmt	SAI	SRI	PVA Max	CVP	IAI	CEI	Sph	Cyl	X
AB	M	63	10/20/97	OD	0.00	PARK	0.52	0.91	0.0969	16.61	0.42	0.51	-4.00	1.25	15
AB	M	63	1/27/98	OD	0.00	PARK	0.49	0.98	0.0969	15.89	0.46	0.39	-4.00	1.25	15
AB	M	63	4/14/98	OD	0.00	PARK	0.27	0.42	0.0000	14.40	0.30	0.48	-4.00	1.25	15
AB	M	63	7/28/98	OD	3.00	PARK	0.49	0.89	0.0969	18.29	0.60	-0.43	0.00	0.50	150
AB	M	63	10/20/97	OS	0.00	PARK	0.35	0.30	0.0000	14.53	0.27	0.51	-3.50	1.25	10
AB	M	63	12/8/97	OS	1.00	PARK	0.66	0.82	0.0969	20.61	0.56	-0.51	0.50	0.50	85
AB	M	63	1/27/98	OS	3.00	PARK	0.59	0.85	0.0969	20.13	0.60	-0.51	0.75	0.25	110
AB	M	63	4/14/98	OS	6.00	PARK	0.31	0.68	0.0969	15.62	0.50	-0.40	0.00	0.25	125
AB	M	63	7/28/98	OS	9.00	PARK	0.50	0.56	0.0000	16.71	0.52	-0.47	0.00	0.25	115
AC	M	42	7/14/98	OD	0.00	LASIK	0.38	0.80	0.0969	22.20	0.34	0.48			
AC	M	42	8/4/98	OD	0.25	LASIK	0.38	0.73	0.0969	47.61	0.52	-0.73	-2.00	0.75	080
AC	M	43	9/4/98	OD	1.00	LASIK	0.34	0.21	-0.1249	47.60	0.48	-0.73	-2.00		
AC	M	42	8/4/98	OS	0.00	LASIK	0.17	0.26	-0.1249	21.29	0.21	0.38	-9.75	1.75	082
AC	M	43	9/4/98	OS	1.00	LASIK	0.48	0.50	0.0000	47.98	0.51	-0.75	-1.25		
AG	F	30	11/17/97	OD	0.00	PARK	0.32	0.26	-0.1249	14.10	0.23	0.36	-6.75	1.00	95
AG	F	28	6/23/98	OD	2.00	PARK	0.41	0.85	0.0969	36.22	0.63	-0.73	1.00	0.25	38
AG	F	30	11/17/97	OS	0.00	PARK	0.21	0.32	0.0000	17.83	0.27	0.43	-6.75	1.00	90
AG	F	30	1/13/98	OS	1.00	PARK	0.54	0.95	0.0969	39.43	0.62	-0.72	0.50	0.75	35
AG	F	30	3/3/98	OS	3.00	PARK	0.24	0.65	0.0000	31.93	0.60	-0.68	0.00		
AG	F	28	6/23/98	OS	6.00	PARK	0.29	0.63	0.0000	30.36	0.40	-0.68	-0.25		
AJ	M	56	11/21/97	OD	15.00	PRK	0.20	0.07	-0.1249	10.77	0.25	-0.37	0.00		
AJ	M	56	2/17/98	OD	18.00	PRK	0.29	0.39	0.0000	12.16	0.25	-0.41	-0.50		
AJ	M	55	11/1/96	OS	0.00	PRK	0.27	1.21	0.1761	8.98	0.40	0.30	-3.75		
AJ	M	56	11/21/97	OS	9.00	PRK	1.40	1.51	0.3010	35.36	0.56	-0.26	-0.50	1.50	170
AJ	M	56	2/17/98	OS	12.00	PRK	0.95	0.77	0.0969	12.16	0.44	-0.35	-0.75	1.25	20
AK	F	53		OD	0.00	LASIK									
AK	F	53	5/26/98	OD	0.00	LASIK	0.95	1.12	0.1761	20.52	0.55	0.56	-7.75	1.25	160
AK	F	53	9/1/98	OD	1.00	LASIK	0.85	0.65	0.0000	34.38	0.58	-0.63	-1.00	1.25	173
AK	F	53	11/3/98	OD	3.00	LASIK	0.98	0.59	0.0000	39.70	0.58	-0.63	-1.00	0.75	172
AK	F	53	5/26/98	OS	0.00	LASIK	0.49	0.44	0.0000	14.57	0.39	0.54	-9.00	1.00	25
AK	F	53	9/1/98	OS	1.00	LASIK	0.76	0.77	0.0969	43.01	0.65	-0.73	-0.50	0.75	014
AK	F	53	11/3/98	OS	3.00	LASIK	0.51	0.68	0.0969	50.41	0.60	-0.72	-1.50	0.50	008
AM	F	53	9/29/97	OD	0.00	PRKv	0.41	0.19	-0.1249				-5.75		
AM	F	54	1/12/98	OD	2.00	PRKv	0.15	0.34	0.0000	19.99	0.48	-0.57	-2.25		
AM	F	54	4/13/98	OD	5.00	PRKv	0.66	0.45	0.0000	17.10	0.38	-0.52	-1.75		
AM	F	54	7/13/98	OD	8.00	PRKv	0.66	0.45	0.0000	14.99	0.37	-0.48	-2.25		
AM	F	53	9/29/97	OS	0.00	PARK	0.26	0.42	0.0000				-6.25	0.50	90
AM	F	54	11/3/97	OS	1.00	PARK	0.46	0.85	0.0969	35.26	0.51	-0.71	0.25	0.25	90
AM	F	54	1/12/98	OS	3.00	PARK	0.49	0.48	0.0000	29.35	0.48	-0.66	-0.50	0.25	90
AM	F	54	4/13/98	OS	6.00	PARK	0.40	0.12	-0.1249	27.32	0.34	-0.64	-0.50	0.50	93
AM	F	54	7/13/98	OS	9.00	PARK	0.40	0.12	-0.1249	25.39	0.48	-0.62	-0.75	0.50	95
BS	F	38	5/24/97	OD	0.00	PARK	0.19	0.42	0.0000	15.32	0.36	0.30	-8.00	0.75	116
BS	F	39	11/7/97	OD	6.00	PARK	0.47	0.74	0.0969	53.47	0.49	-0.76	-0.25	1.00	75
BS	F	39	6/9/98	OD	12.00	PARK	0.71	0.72	0.0969	51.14	0.49	-0.74	-0.50	0.75	75
BS	F	40	9/11/98	OD	16.00	PARK	0.68	0.68	0.0969	52.06	0.51	-0.74	-1.00	1.25	80
BS	F	39	11/7/97	OS	0.00	LASIK	1.97	0.84	0.0969	21.76	0.50	-0.20	-9.50	1.00	55
BS	F	39	6/9/98	OS	0.00	LASIK	0.61	1.18	0.1761	17.31	0.45	0.36	-10.75	1.75	55
BS	F	40	9/11/98	OS	1.00	FLAP	0.57	0.62	0.0000	19.82	0.40	0.10	-11.00	2.25	55
BY	F	47	1/24/97	OD	0.00	PRK	0.34	0.80	0.0969	22.36	0.37	0.71	-7.00	0.75	135
BY	F	48	11/7/97	OD	9.00	PRK	0.51	0.48	0.0969	31.74	0.45	-0.64	-0.25	0.50	90
BY	F	48	2/17/98	OD	12.00	PRK	0.79	0.08	-0.1249	31.47	0.37	-0.63	-0.25	0.75	85
BY	F	48	8/24/98	OD	18.00	PRK	0.39	0.46	0.0000	29.50	0.39	-0.63	-0.50	0.75	085
BY	F	48	11/7/97	OS	0.00	LASIK	0.75	0.73	0.0969	24.26	0.39	0.72	-8.25	0.75	85
BY	F	48	2/17/98	OS	2.00	LASIK	0.55	0.47	0.0000	27.89	0.52	-0.58	-2.25	0.50	10
BY	F	48	8/24/98	OS	3.00	LASIK	0.38	0.38	0.0000	34.80	0.54	-0.67	-1.50	0.50	080
CA	M	52	3/25/98	OD	0.00	PARK	0.38	0.79	0.0969	21.23	0.34	0.42	-7.25	2.50	60
CA	M	52	6/29/98	OD	3.00	PARK	0.49	0.35	0.0000	23.31	0.42	-0.52	0.00		
CA	M	52	10/2/98	OD	6.00	PARK	0.96	0.86	0.0969	26.36	0.51	-0.51	-0.50	0.00	0
CA	M	52	3/25/98	OS	0.00	PARK	0.23	0.87	0.0969	21.90	0.32	0.45	-5.25	2.50	120
CA	M	52	6/29/98	OS	0.00	PARK	0.23	0.87	0.0969	23.22	0.50	0.40	-5.25	2.50	120
CA	M	52	10/2/98	OS	3.00	PARK	0.59	1.17	0.1761	19.96	0.52	-0.42	-0.25	0.50	45
CC	M	46	11/10/97	OD	3.00	PRK	0.93	1.71	0.3010	52.62	0.82	-0.79	1.50	0.50	115
CC	M	47	2/9/98	OD	6.00	PRK	0.89	1.25	0.1761	47.86	0.75	-0.77	0.25	0.50	120
CC	M	47	5/4/98	OD	9.00	PRK	0.75	1.32	0.1761	52.91	0.66	-0.78	1.00	0.50	120
CC	M	46	6/24/97	OS	0.00	LASIK	1.28	1.95	0.3010	41.50	0.74	0.46			

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Subj	M/F	Age	Date	Eye	Visit	Tmt	SAI	SRI	PVA Max	CVP	IAI	CEI	Sph	Cyl	X
CC	M	46	11/10/97	OS	4.00	LASIK	1.24	1.58	0.3010	84.01	0.83	-0.84	-0.50	1.50	175
CC	M	47	2/9/98	OS	7.00	LASIK	0.92	1.13	0.1761	76.86	0.98	-0.86	-0.25	1.25	165
CC	M	47	5/4/98	OS	10.00	LASIK	0.77	0.88	0.0969	91.60	0.62	-0.84	-0.50	0.50	170
CC	M	47	5/4/98	OS	10.00	LASIK	0.92	1.13	0.1761	91.60	0.62	-0.84	-0.50	0.50	171
CE	F	49	11/3/97	OD	0.00	PARKv	0.45	0.69	0.0969	23.02	0.30	0.51	-7.25	1.50	115
CE	F	49	2/3/98	OD	1.00	PARKv	0.96	0.63	0.0000	37.12	0.74	-0.52	-0.25	3.25	135
CE	F	49	4/24/98	OD	4.00	PARKv	0.38	0.60	0.0000	32.93	0.54	-0.59	-1.00	1.50	15
CE	F	49	7/31/98	OD	7.00	PARKv	0.41	0.33	0.0000	34.40	0.61	-0.57	-2.00	1.00	85
CE	F	49	11/3/97	OS	0.00	PARK	0.22	1.07	0.1761	26.62	0.42	0.58	-8.00	2.00	82
CE	F	49	12/2/97	OS	1.00	PARK	0.34	1.04	0.1761				-0.25	0.75	70
CE	F	49	2/3/98	OS	3.00	PARK	0.57	0.36	0.0000	38.69	0.45	-0.64	-0.75	0.50	47
CE	F	49	4/24/98	OS	6.00	PARK	0.47	0.26	-0.1249	36.47	0.41	-0.58	-0.75		
CE	F	49	7/31/98	OS	9.00	PARK	0.68	0.21	-0.1249	36.14	0.45	-0.59	-0.75	0.25	75
CH	M	33	6/24/97?	OD	0.00	PRK							-6.75		
CH	M	34	3/13/98	OD	7.00	PRK	0.34	0.71	0.0969	37.31	0.57	-0.72	-0.25		
CH	M	34	6/5/98	OD	9.00	PRK	0.33	0.43	0.0000	36.60	0.54	-0.71	-0.25		
CH	M	34	11/21/97	OS	0.00	PRK	0.26	0.50	0.0000	11.86	0.38	0.39	-5.75	0.50	75
CH	M	34	3/13/98	OS	3.00	PRK	0.46	1.14	0.1761	42.87	0.77	-0.61	-1.25	1.00	103
CH	M	34	6/5/98	OS	6.00	PRK	0.25	0.52	0.0000	28.18	0.49	-0.65	-1.00	1.25	90
CM	M	48	6/10/98	OD	0.00	LASIK	0.38	0.76	0.0969	17.86	0.40	0.54			
CM	M	48	8/4/98	OD	0.25	LASIK	0.84	0.79	0.0969	40.07	0.55	-0.70	-1.00	1.00	015
CM	M	48	9/1/98	OD	1.00	LASIK	0.84	0.79	0.0969	35.50	0.50	-0.69	-1.75	1.25	007
CM	M	48	10/20/98	OD	3.00	LASIK	0.52	0.65	0.0000	34.39	0.46	-0.68	-2.00	1.50	003
CM	M	48	8/4/98	OS	0.00	LASIK	0.24	0.12	-0.1249	11.23	0.28	0.40	-9.25	1.75	029
CM	M	48	9/1/98	OS	0.00	LASIK	0.24	0.12	-0.1249	11.23	0.28	0.40	-9.00	1.50	037
CM	M	48	10/20/98	OS	1.00	LASIK	0.30	0.19	-0.1249	36.21	0.47	-0.71	-1.25	0.75	165
CR	M	27	10/3/97	OD	0.00	PRK	0.09	0.42	0.0000	13.55	0.22	0.48	-6.00	0.50	95
CR	M	27	6/15/97	OS	0.00	PRK									
CR	M	27	6/23/97	OS	0.00	PRK	0.39	0.25	-0.1249	10.85	0.15	0.41	-5.50		
CR	M	27	10/3/97	OS	3.00	PRK	0.26	0.68	0.0969	40.18	0.47	-0.72	0.00	0.50	165
CT	F	53	5/19/98	OD	2.00	RING	0.40	0.68	0.0969	32.80	0.79	0.92	51	-1.75	0.25
CT	F	53	6/19/98	OD	3.00	RING	0.51	0.63	0.0000	38.86	0.79	0.77	46	-2.00	0.75
CT	F	53	5/19/98	OS	0.00	RING	1.11	0.89	0.0969	13.64	0.37	0.32	96	-3.25	0.25
CT	F	53	6/19/98	OS	0.00	RING	0.17	0.84	0.0969	10.87	0.39	0.34	100	-3.25	0.25
CVP	F	61	1/2/98	OD	0.00	PARK	0.20	0.30	0.0000	16.33	0.41	0.64	-4.25	1.25	10
CVP	F	61	2/27/98	OD	1.00	PARK	0.19	0.75	0.0969	14.10	0.55	0.03	0.25	0.25	150
CVP	F	61	4/9/98	OD	3.00	PARK	0.22	0.85	0.0969	12.56	0.52	0.20	0.00		
CVP	F	61	5/18/98	OD	4.00	PARK	0.13	0.60	0.0000	12.26	0.51	-0.14	0.00		
CVP	F	62	7/20/98	OD	6.00	PARK	0.21	0.62	0.0000	11.29	0.49	-0.23	0.25	0.25	045
CVP	F	62	10/2/98	OD	9.00	PARK	0.20	0.35	0.0000	12.42	0.40	0.18	0.00	0.50	30
CVP	F	61	1/2/98	OS	0.00	PARK	0.16	0.14	-0.1249	14.01	0.27	0.59	-3.50	0.75	178
CVP	F	61	4/9/98	OS	0.00	PARK	0.25	0.10	-0.1249	12.15	0.28	0.51	-3.75	0.75	178
CVP	F	61	5/18/98	OS	1.00	PARK	0.25	0.42	0.0000	14.61	0.44	-0.37	0.75		
CVP	F	62	7/20/98	OS	3.00	PARK	0.51	0.63	0.0000	14.99	0.47	-0.30	0.75	0.25	170
CVP	F	62	10/2/98	OS	6.00	PARK	0.39	0.36	0.0000	17.24	0.38	-0.34	0.50	0.50	15
DG	F	35	9/25/98	OD	10.00	PRKv	0.70	1.02	0.1761	20.85	0.59	-0.58	-0.50		
DG	F	35	9/25/98	OS	10.00	PRKv	0.21	0.72	0.0969	22.61	0.54	-0.60	-0.25		
DH	M	54	5/22/98	OD	0.00	LASIK	0.26	0.16	-0.1249	12.98	0.19	0.55	-5.75	0.75	163
DH	M	54	7/30/98	OD	1.00	LASIK	0.47	0.61	0.0000	12.66	0.52	-0.43	-1.00	0.50	160
DH	M	54	5/22/98	OS	0.00	LASIK	0.30	0.59	0.0000	12.83	0.24	0.54	-5.75		
DH	M	54	7/30/98	OS	1.00	LASIK	0.39	0.71	0.0969	17.32	0.57	-0.53	-0.75		
DKX	M	38	12/18/96	OD	0.00	PRK	0.20	0.31	0.0000	14.51	0.34	0.29	-10.00	0.25	93
DKX	M	38	8/15/97	OD	6.00	PRK	0.58	0.66	0.0000	47.25	0.63	-0.79	0.00	0.50	88
DKX	M	39	10/21/97	OD	9.00	PRK	0.73	0.63	0.0000	58.53	0.71	-0.81	0.00	0.25	90
DKX	M	39	12/16/97	OD	11.00	PRK	0.48	0.71	0.0969	60.31	0.60	-0.81	0.00		
DKX	M	39	1/16/98	OD	12.00	PRK	0.43	0.99	0.0969	54.70	0.74	-0.79	0.50		
DKX	M	39	8/17/98	OD	18.00	PRK	0.46	0.81	0.0969	42.55	0.62	-0.78	-0.50	0.50	075
DKX	M	38	8/15/97	OS	0.00	PRK	0.11	0.35	0.0000	16.14	0.27	0.34	-11.00	0.50	76
DKX	M	39	10/21/97	OS	1.00	PRK	1.44	1.78	0.3010	132.22	1.08	-0.90	0.75	1.00	82
DKX	M	39	12/16/97	OS	3.00	PRK	0.42	0.33	0.0000	64.22	0.57	-0.83	0.50		
DKX	M	39	1/16/98	OS	4.00	PRK	0.46	0.48	0.0000	57.55	0.56	-0.82	0.50		
DKX	M	39	8/17/98	OS	11.00	PRK	0.25	0.39	0.0000	59.17	0.60	-0.82	0.25	0.75	091
DKY	M	31	3/19/97	OD	0.00	PARK	0.19	0.78	0.0969	18.64	0.39	0.34	-4.50	1.75	127
DKY	M	31	9/12/97	OD	6.00	PARK	0.37	0.75	0.0969	21.86	0.39	-0.54	0.00	0.25	20
DKY	M	31	1/23/98	OD	9.00	PARK	0.29	0.61	0.0000	18.08	0.47	-0.53	-0.25		

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Subj	M/F	Age	Date	Eye	Visit	Tmt	SAI	SRI	PVA Max	CVP	IAI	CEI	Sph	Cyl	X
DKY	M	32	3/27/98	OD	12.00	PARK	0.09	0.30	0.0000	20.98	0.54	-0.57	-0.25	0.25	90
DS	F	45	7/15/98	OD	0.00	LASIK	0.27	0.55	0.0000	10.56	0.25	0.33			
DS	F	45	8/4/98	OD	0.25	LASIK	5.20	3.35	0.5441	153.56	1.18	-0.85	-1.50	0.50	005
DS	F	45	8/4/98	OS	0.00	LASIK	0.20	0.09	-0.1249	9.66	0.20	0.33	-14.00	0.75	068
EO	M	42	4/23/97	OD	0.00	PARK	0.34	0.47	0.0000	20.05	0.30	0.32	-5.25	1.25	105
EO	M	43	11/10/97	OD	3.00	PARK	0.19	0.25	-0.1249	23.84	0.38	-0.49	-0.25	0.50	85
EO	M	43	2/2/98	OD	6.00	PARK	0.26	0.20	-0.1249	26.74	0.30	-0.55	0.00		
EO	M	43	5/11/98	OD	9.00	PARK	0.23	0.46	0.0000	21.43	0.41	-0.50	-0.75	0.25	097
EO	M	42	4/23/97	OS	0.00	PARK	0.06	0.69	0.0969	16.45	0.33	0.27	-5.00	0.75	78
EO	M	43	11/10/97	OS	6.00	PARK	0.35	0.77	0.0969	33.87	0.47	-0.60	-1.25	0.50	40
EO	M	43	2/2/98	OS	9.00	PARK	0.29	0.80	0.0969	24.66	0.34	-0.47	-2.00	0.50	37
EO	M	43	5/11/98	OS	12.00	PARK	0.41	0.65	0.0000	22.80	0.51	-0.44	-3.00	0.75	075
GA	M	42	9/16/97	OD	0.00	PRK	0.12	0.00	-0.1249	13.57	0.28	0.35	-4.50	0.50	90
GA	M	42	7/17/97	OD	0.00	PRK	0.08	0.00	-0.1249	12.75	0.24	0.37			
GA	M	42	10/30/97	OD	1.00	PRK	0.23	0.11	-0.1249	34.55	0.39	-0.69	0.00	0.75	93
GA	M	42	12/23/97	OD	3.00	PRK	0.13	0.20	-0.1249	25.56	0.40	-0.62	0.00	0.25	90
GA	M	42	2/3/98	OD	4.00	PRK	0.28	0.38	0.0000	24.10	0.42	-0.61	0.00		
GA	M	42	3/24/98	OD	6.00	PRK	0.15	0.04	-0.1249	23.88	0.33	-0.60	0.00		
GA	M	43	6/18/98	OD	9.00	PRK	0.29	0.57	0.0000	23.92	0.45	-0.59	-0.25		
GA	M	43	10/5/98	OD	12.00	PRK	0.40	0.37	0.0000	24.72	0.38	-0.59	-0.50	0.50	90
GA	M	42	9/16/97	OS	0.00	PARK	0.33	0.00	-0.1249	15.16	0.25	0.41	-3.25	0.75	82
GA	M	42	12/23/97	OS	0.00	PARK	0.13	0.04	-0.1249	12.96	0.24	0.41	-3.25	0.75	82
GA	M	42	12/23/97	OS	0.00	PARK	0.13	0.04	-0.1249	12.96	0.24	0.41	-3.00	0.75	90
GA	M	42	2/3/98	OS	1.00	PARK	0.48	0.60	0.0000	18.46	0.46	-0.49	0.00	0.50	75
GA	M	42	3/24/98	OS	3.00	PARK	0.23	0.50	0.0000	16.26	0.40	-0.43	0.00		
GA	M	43	6/18/98	OS	6.00	PARK	0.27	0.25	-0.1249	14.79	0.29	-0.41	-0.25	0.25	70
GA	M	43	10/5/98	OS	9.00	PARK	0.25	0.23	-0.1249	16.20	0.32	-0.42	-0.25	0.50	60
GU	F	38	10/23/97	OD	0.00	PRK	0.20	1.06	0.1761	10.76	0.43	0.39	-5.50	0.25	50
GU	F	38	6/24/97	OD	0.00	PRK	0.10	0.25	-0.1249	11.25	0.18	0.42			
GU	F	38	12/23/97	OD	1.00	PRK	0.51	0.53	0.0000	38.68	0.44	-0.72	0.50		
GU	F	38	2/19/98	OD	3.00	PRK	0.72	0.64	0.0000	32.30	0.45	-0.67	-0.25		
GU	F	38	6/9/98	OD	6.00	PRK	0.16	0.20	-0.1249	27.80	0.36	-0.66	0.25		
GU	F	37	6/24/97	OS	0.00	PRK	0.44	0.91	0.0969	10.96	0.35	0.36	-6.75	0.50	125
GU	F	38	10/23/97	OS	3.00	PRK	0.62	1.05	0.1761	42.07	0.58	-0.72	0.25	0.25	95
GU	F	38	2/19/98	OS	6.00	PRK	0.26	0.14	-0.1249	37.24	0.37	-0.70	0.00		
GU	F	38	6/9/98	OS	9.00	PRK	0.51	0.45	0.0000	36.87	0.43	-0.70	0.00		
JF	M	35	10/17/97	OD	0.00	PARK	0.12	0.78	0.0969	13.95	0.46	0.54	-7.75	0.50	90
JF	M	35	1/12/98	OD	3.00	PARK	0.47	0.61	0.0000	31.56	0.44	-0.66	0.00		
JF	M	35	6/9/98	OD	6.00	PARK	0.50	0.80	0.0969	33.92	0.57	-0.67	-0.25	0.25	90
JF	M	34	7/21/97	OS	0.00	PARK	0.13	0.36	0.0000	11.99	0.34	0.54	-6.75	0.50	125
JF	M	35	10/17/97	OS	3.00	PARK	0.41	0.36	0.0000	26.37	0.41	-0.64	-0.25	0.50	65
JF	M	35	1/12/98	OS	6.00	PARK	0.50	0.15	-0.1249	29.23	0.43	-0.63	0.00	0.50	45
JF	M	35	6/9/98	OS	9.00	PARK	0.45	0.40	0.0000	27.91	0.48	-0.62	-0.25	0.75	45
JG	F	28	10/6/97	OD	6.00	Ring	0.27	0.44	0.0000	30.51	0.69	0.69	100	-1.25	1.25
JG	F	28	11/18/97	OD	7.00	Ring	0.24	0.27	-0.1249	27.35	0.56	0.57	100	-1.25	1.50
JG	F	28	1/13/98	OD	9.00	Ring	0.28	0.21	-0.1249	29.73	0.61	0.68	112	-0.50	1.25
JG	F	28	10/6/97	OS	0.00	Ring	0.76	0.79	0.0969	14.31	0.42	0.53	80	-2.75	
JG	F	28	11/18/97	OS	1.00	Ring	0.55	0.37	0.0000	44.08	0.82	0.99	80	-1.50	1.00
JG	F	28	1/13/98	OS	3.00	Ring	0.39	0.42	0.0000	46.27	0.78	0.84	80	-0.75	1.50
JH	F	36	9/5/97	OD	0.00	PRK	0.36	0.60	0.0000	18.78	0.32	0.37	-9.75	1.00	103
JH	F	36	10/20/97	OD	1.00	PRK	0.56	0.93	0.0969	49.25	0.73	-0.81	-1.00	1.25	80
JH	F	36	11/21/97	OD	2.00	PRK	0.40	0.47	0.0000	68.71	0.65	-0.81	-0.75	0.75	75
JH	F	36	12/29/97	OD	3.00	PRK	0.28	0.29	0.0000	67.69	0.58	-0.81	-0.75	1.25	85
JH	F	36	3/9/98	OD	6.00	PRK	0.64	0.39	0.0000	66.48	0.63	-0.82	0.25	1.25	60
JH	F	37	6/9/98	OD	9.00	PRK	0.68	0.73	0.0969	64.76	0.57	-0.80	-0.50	1.00	75
JH	F	37	10/15/98	OD	12.00	PRK	0.53	0.29	0.0000	69.18	0.53	-0.81	-0.50	1.00	75
JH	F	36	4/18/97	OS	0.00	PARK	0.35	0.98	0.0969	21.52	0.46	0.31	-8.00	1.25	90
JH	F	36	9/5/97	OS	3.00	PARK	0.69	0.33	0.0000	64.16	0.46	-0.81	0.25	0.25	55
JH	F	36	11/21/97	OS	6.00	PARK	0.24	0.59	0.0000	61.52	0.52	-0.80	0.00		
JH	F	36	3/9/98	OS	9.00	PARK	0.20	0.24	-0.1249	61.01	0.45	-0.80	0.50		
JH	F	37	6/9/98	OS	12.00	PARK	0.41	0.30	0.0000	63.53	0.48	-0.80	0.25		
JH	F	37	10/15/98	OS	17.00	PARK	0.23	0.15	-0.1249	60.49	0.44	-0.80	0.00	0.25	170
JN	M	55	6/5/97	OD	0.00	PARK							-8.00	1.50	120
JN	M	55	9/19/97	OD	0.00	PARK	0.58	0.50	0.0000	14.36	0.32	0.34	-8.00	1.50	120
JN	M	56	11/14/97	OD	1.00	PARK	1.16	0.98	0.0969	21.74	0.62	-0.54	-1.50	0.50	85

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Subj	M/F	Age	Date	Eye	Visit	Tmt	SAI	SRI	PVA Max	CVP	IAI	CEI	Sph	Cyl	X
JN	M	56	12/16/97	OD	2.00	PARK	1.10	0.53	0.1761	20.58	0.68	-0.58	-2.00	1.00	100
JN	M	56	3/16/98	OD	5.00	PARK	0.14	0.46	0.0000	21.59	0.45	-0.60	-2.00	1.00	118
JN	M	56	6/8/98	OD	8.00	PARK	0.25	0.65	0.0000	19.05	0.43	-0.58	-2.00	1.00	120
JN	M	55	6/5/97	OS	0.00	PARK	0.34	0.84	0.0969	8.42	0.35	0.37	-7.25	0.75	50
JN	M	55	9/19/97	OS	3.00	PARK	0.62	1.27	0.1761	42.98	0.71	-0.71	-0.50	0.25	105
JN	M	55	11/14/97	OS	5.00	PARK	0.21	0.90	0.0969	33.07	0.55	-0.66			
JN	M	56	12/16/97	OS	6.00	PARK	0.45	0.45	0.0000	38.62	0.51	-0.68	-0.75	0.50	100
JN	M	56	3/16/98	OS	9.00	PARK	0.45	0.46	0.0000	34.96	0.41	-0.66	-1.00	0.50	90
JN	M	56	6/8/98	OS	12.00	PARK	0.28	0.52	0.0000	32.61	0.46	-0.65	-0.75	0.25	95
JPX	M	57	10/21/97	OD	6.00	PRK	0.50	0.65	0.0000	25.51	0.49	-0.52			
JPX	M	57	4/27/98	OD	12	PRK	0.32	0.81	0.0969	24.96	0.44	-0.53	0.00		
JPX	M	57	4/27/98	OS	0	PRK	0.44	0.11	-0.1249	20.75	0.31	0.52	-4.00	1.50	075
JPX	M	57	10/21/97	OS	0	PRK	0.39	0.13	-0.1249	21.31	0.24	0.56			
JR	M	38	11/25/97	OD	6	PARK	0.05	0.33	0.0000	16.16	0.30	-0.49			
JR	M	38	4/28/98	OD	12.00	PARK	0.20	0.20	-0.1249	16.64	0.33	-0.51	-0.25	0.50	50
JR	M	38	11/25/97	OS	0.00	PARK	0.25	0.42	0.0000	13.28	0.36	0.36	-4.25	1.25	78
JR	M	38	4/28/98	OS	4.00	PARK	0.24	0.64	0.0000	16.42	0.34	-0.49	0.00		
JRX	M	29	5/4/98	OD	12.00	PARK	0.32	0.62	0.0000	36.64	0.58	-0.68	-0.25	0.25	38
JRX	M	29	5/4/98	OS	9.00	PARK	0.36	0.48	0.0000	28.05	0.39	-0.64	-0.25		
JW	F	54	12/30/97	OD	0.00	PRK	0.31	0.01	-0.1249	11.65	0.35	0.40	-14.00	0.75	175
JW	F	54	12/30/97	OS	9.00	PRK	1.86	0.72	0.0969	95.68	0.48	-0.69	0.00	1.00	85
JWX	F	43	4/6/98	OD	0.00	LASIK	0.95	0.44	0.0969	17.46	0.38	0.43	-12.50	1.50	125
JWX	F	43	4/6/98	OS	0.00	LASIK	1.04	0.83	0.1761	19.05	0.50	0.39	-12.75	1.50	70
JWX	F	43	6/29/98	OS		FLAP	0.72	1.36	0.1761	35.04	0.51	0.44			
KA	F	44	4/9/98	OD	0.00	LASIK	0.21	0.66	0.0000	15.31	0.34	0.49	-11.00	0.25	80
KA	F	44	10/20/97	OS	0.00	LASIK	0.28	0.74	0.0969	18.28	0.28	0.47			
KA	F	44	4/9/98	OS	0.00	LASIK	0.49	1.52	0.3010	23.20	0.46	0.47	-10.75	1.25	105
KC	F	32	4/13/98	OD	0.00	LASIK	0.13	0.53	0.0000	12.65	0.38	0.55	-8.50	0.25	95
KC	F	32	4/13/98	OS	0.00	LASIK	0.11	0.33	0.0000	12.82	0.35	0.58	-8.25	0.75	40
KC	F	32	7/2/98	OS	3.00	LASIK	0.27	0.66	0.0000	34.98	0.51	-0.68			
LC	F	57	12/11/97	OD	0.00	PRK	0.44	0.55	0.0000	10.91	0.31	0.42	-6.50	0.50	55
LC	F	57	8/21/97	OD	0.00	PRK	0.09	0.65	0.0000	9.36	0.35	0.45			
LC	F	57	3/24/98	OD	3.00	PRK	0.19	0.79	0.0969	36.60	0.59	-0.72	-0.25	0.50	55
LC	F	58	6/9/98	OD	6.00	PRK	0.93	0.58	0.0969	34.56	0.57	-0.70	0.00	0.75	70
LC	F	57	8/21/97	OS	0.00	PARK	0.14	0.42	0.0000	12.88	0.26	0.42	-7.25	1.00	135
LC	F	57	3/24/98	OS	6.00	PARK	0.56	0.68	0.0969	38.31	0.44	-0.68	0.25	0.50	55
LC	F	58	6/9/98	OS	9.00	PARK	0.83	0.55	0.0969	32.80	0.48	-0.65	0.00	0.50	70
LM	F	43	10/10/97	OD	0.00	PARK	1.55	1.40	0.1761	24.05	0.47	0.55	-6.50	1.00	95
LM	F	44	2/27/98	OD	3.00	PARK	0.42	0.68	0.0969	33.47	0.47	-0.61	0.00	0.25	120
LM	F	44	6/15/98	OD	6.00	PARK	0.73	0.71	0.0969	31.71	0.51	-0.52	0.00	0.25	120
LM	F	44	9/28/98	OD	9.00	PARK	0.51	0.20	-0.1249	32.05	0.42	-0.53	-0.50	0.25	120
LM	F	43	10/10/97	OS	12.00	PRK	0.31	0.30	0.0000	17.64	0.45	-0.43	-0.50		
LM	F	44	2/27/98	OS	16.00	PRK	0.79	0.62	0.0000	20.29	0.46	-0.46	-1.00		
LM	F	44	6/15/98	OS	20.00	PRK	0.16	0.30	0.0000	17.35	0.42	-0.45	-0.75		
LM	F	44	9/28/98	OS	24.00	PRK	1.07	0.58	0.1761	17.11	0.49	-0.43	-1.00	0.00	0
MBX	M	32	9/9/97	OD	9.00	PRK	0.20	0.60	0.0000	66.78	0.68	-0.81			
MBX	M	32	11/21/97	OD	12.00	PRK	0.25	0.46	0.0000	52.83	0.76	-0.78	-0.25		
MBX	M	32	6/5/98	OD	18.00	PRK	0.69	0.53	0.0000	62.75	0.61	-0.79			
MBX	M	32	5/23/97	OS	0.00	PRK	0.12	0.00	-0.1249	11.67	0.18	0.49	-11.25		
MBX	M	32	9/9/97	OS	3.00	PRK	3.36	2.41	0.3979	106.06	0.87	-0.85			
MBX	M	32	11/21/97	OS	6.00	PRK	0.57	0.71	0.0969	76.71	0.61	-0.83	0.50	0.50	88
MBX	M	32	6/5/98	OS	12.00	PRK	0.57	0.71	0.0969	76.71	0.61	-0.83			
MBY	F	49	3/14/97	OD	0.00	PRK	0.51	0.47	0.0000	15.58	0.20	0.36			
MBY	F	49	9/16/97	OD	0.00	PRK	0.12	0.00	-0.1249	15.67	0.21	0.53			
MBY	F	49	10/10/97	OD	0.00	PRK	0.80	0.50	0.0000	12.72	0.32	0.40	-6.75		
MBY	F	49	3/14/97	OS	0.00	PRK	0.12	0.36	0.0000	13.13	0.16	0.39			
MBY	F	49	4/4/97	OS	0.00	PRK	0.54	1.35	0.1761	11.60	0.53	0.28			
MBY	F	49	9/16/97	OS	5.00	PRK	0.34	0.74	0.0969	66.17	0.56	-0.80			
MBY	F	49	10/10/97	OS	6.00	PRK	0.34	0.74	0.0969	66.17	0.56	-0.80	1.50	1.00	128
ML	F	51	5/7/97	OD	0.00	PARK	0.21	0.97	0.0969	12.48	0.38	0.45	-8.00	1.25	38
ML	F	52	8/11/97	OD	3.00	PARK	0.47	0.00	-0.1249	33.81	0.31	-0.69	0.50		
ML	F	52	11/17/97	OD	6.00	PARK	0.63	0.54	0.0000	33.35	0.33	-0.68	0.00		
ML	F	52	3/2/98	OD	9.00	PARK	0.13	0.34	0.0000	32.71	0.28	-0.68	0.00		
ML	F	52	5/18/98	OD	12.00	PARK	0.47	0.18	-0.1249	35.58	0.25	-0.69	0.50	0.25	115
ML	F	53	8/3/98	OD	15.00	PARK	0.43	0.15	-0.1249	31.53	0.34	-0.66	-0.25		

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Subj	M/F	Age	Date	Eye	Visit	Tmt	SAI	SRI	PVA Max	CVP	IAI	CEI	Sph	Cyl	X
ML	F	52	5/7/97	OS	0.00	PRK	0.54	0.90	0.0969	12.49	0.35	0.46			
ML	F	52	8/11/97	OS	0.00	PRK	0.33	0.52	0.0000	12.86	0.28	0.46	-7.75		
ML	F	52	9/19/97	OS	1.00	PRK	0.56	1.57	0.3010	69.22	0.63	-0.80	3.25	0.50	150
ML	F	52	11/17/97	OS	3.00	PRK	0.30	0.56	0.0000	43.12	0.40	-0.73	0.00	0.75	105
ML	F	52	3/2/98	OS	6.00	PRK	0.37	0.58	0.0000	39.05	0.35	-0.70	-0.25	0.50	95
ML	F	52	5/18/98	OS	9.00	PRK	0.26	0.33	0.0000	41.34	0.33	-0.72	0.25	0.50	95
ML	F	53	8/3/98	OS	12.00	PRK	0.29	0.41	0.0000	36.15	0.40	-0.69	-0.25	0.50	110
MN	M	41	6/19/98	OD	0.00	PARK	0.23	0.45	0.0000	14.70	0.35	0.57			
MN	M	41	8/4/98	OD	1.00	PARK	1.65	1.25	0.1761	66.50	0.70	-0.75	0.75	0.50	105
MN	M	41	10/2/98	OD	3.00	PARK	4.16	1.72	0.3010	79.57	0.87	-0.77	1.00	0.75	109
MN	M	41	6/19/98	OS	0.00	PARK	0.52	0.82	0.0969	13.64	0.41	0.49	-8.25	2.00	15
MN	M	41	10/2/98	OS	0.00	PARK	0.19	0.32	0.0000	10.96	0.34	0.45	-8.00	1.75	15
MS	F	32	6/23/98	OD	12.00	LASIK	0.57	1.19	0.1761	68.04	0.91	-0.83	-0.50		
MS	F	32	6/23/98	OS	6.00	LASIK	0.35	0.79	0.0969	65.56	0.66	-0.83	-1.50		
MSX	F	45	7/21/98	OD	8.00	PRKv	0.18	0.37	0.0000	32.69	0.49	-0.68	0.25	0.25	40
MSX	F	45	7/21/98	OS	7.00	PRKv	1.05	0.66	0.0000	37.67	0.47	-0.63	-1.50	0.75	140
PB	F	54	10/23/97	OD	0.00	PARK	0.34	0.79	0.0969	23.92	0.36	0.34	-5.50	2.75	77
PB	F	54	12/16/97	OD	1.00	PARK	0.32	0.46	0.0000	19.96	0.48	-0.43	-0.25	0.75	175
PB	F	54	2/3/98	OD	2.00	PARK	0.50	0.19	-0.1249	22.22	0.49	-0.42	-0.50		
PB	F	54	4/7/98	OD	5.00	PARK	0.33	0.33	0.0000	19.93	0.36	-0.43	-0.50	0.25	37
PB	F	54	7/21/98	OD	8.00	PARK	0.44	0.40	0.0000	20.70	0.44	-0.46	-0.50	0.75	050
PB	F	53	6/23/97	OS	0.00	PARK	0.31	0.80	0.0969	26.16	0.40	0.24	-5.75	2.75	110
PB	F	54	10/23/97	OS	3.00	PARK	1.09	0.87	0.0969	28.54	0.45	-0.55	0.50	0.50	105
PB	F	54	12/16/97	OS	5.00	PARK	0.41	0.55	0.0000	27.08	0.41	-0.55	0.75	0.50	68
PB	F	54	2/3/98	OS	7.00	PARK	0.57	0.30	0.0000	27.66	0.39	-0.55	1.00	0.75	67
PB	F	54	4/7/98	OS	9.00	PARK	0.73	0.62	0.0000	25.57	0.44	-0.56	0.50	0.75	55
PB	F	54	7/21/98	OS	12.00	PARK	0.97	0.58	0.0000	25.87	0.43	-0.54	0.50	1.25	063
PM	M	36	12/1/97	OD	16.00	PRK	2.16	2.06	0.3979	42.31	0.75	0.42	-3.75	1.50	178
PM	M	36	1/30/98	OD	18.00	PRK	1.50	1.53	0.3010	38.06	0.59	0.31	-3.50	1.75	18
PM	M	36	5/26/98	OD	21.00	PRK	0.89	1.88	0.3010	35.50	0.60	0.23	-3.75	1.75	16
PM	M	36	5/26/98	OS	0.00	PRK	0.14	0.31	0.0000	17.04	0.23	0.59			
PM	M	36	1/30/98	OS	0.00	PRK	0.58	0.64	0.0000	17.35	0.27	0.55	-6.75		
PR	F	48	11/18/97	OD	0.00	PRK	0.26	0.64	0.0000	15.30	0.32	0.38	-11.75	0.50	22
PR	F	49	3/13/98	OD	0.00	PRK	0.26	0.64	0.0000				-12.25	0.50	35
PR	F	49	7/14/98	OD	1.00	PRK	4.30	2.75	0.4771	151.10	1.15	-0.91	0.75	0.50	115
PR	F	49	8/20/98	OD	2.00	PRK	1.25	1.58	0.3010	80.05	0.95	-0.87	1.50	0.75	127
PR	F	48	11/18/97	OS	0.00	PRK	0.26	0.52	0.0000	22.12	0.37	0.34	-11.00	0.50	100
PR	F	48	12/30/97	OS	1.00	PRK	0.28	1.04	0.1761	71.97	0.73	-0.82	0.75	1.25	150
PR	F	49	3/13/98	OS	3.00	PRK	0.48	0.97	0.0969	61.01	0.78	-0.83	0.00	0.75	150
PR	F	49	6/2/98	OS	6.00	PRK	0.65	0.63	0.0000	70.28	0.69	-0.82	-1.00	2.25	90
PR	F	49	7/14/98	OS	7.00	PRK	0.70	1.06	0.1761	69.65	0.67	-0.82	0.00	1.50	85
PR	F	49	8/20/98	OS	9.00	PRK	0.55	0.73	0.0969	66.42	0.69	-0.82	-0.50	1.50	090
RL	M	31	8/14/98	OD	0.00	LASIKv	0.06	0.49	0.0000	26.82	0.30	0.49	-4.25	3.50	112
RL	M	31	11/20/98	OD	3.00	LASIKv	0.58	0.67	0.0000	24.96	0.49	-0.42	-0.50	1.00	105
RL	M	31	8/14/98	OS	0.00	LASIK	0.02	0.32	0.0000	18.47	0.28	0.50	-8.00	2.00	86
RL	M	31	11/20/98	OS	3.00	LASIK	0.67	0.27	-0.1249	28.18	0.39	-0.56	-3.25	0.75	65
SC	M	31	11/11/97	OD	0.00	PRK	0.27	0.62	0.0000	17.13	0.23	0.28	-6.25	2.50	85
SC	M	31	11/11/97	OS	6.00	PRK	0.23	0.12	-0.1249	43.19	0.40	-0.73			
SJ	M	48	12/30/97	OD	0.00	RING	1.75	0.82	0.0969	17.92	0.41	0.39	80	-3.25	
SJ	M	48	7/28/98	OD	0.00	RING	0.17	0.49	0.0000	8.69	0.46	0.34	80	-3.25	0.25
SJ	M	48	11/19/98	OD	0.00	RING	0.08	0.26	-0.1249	9.04	0.34	0.35	80	-3.50	
SJ	M	48	3/17/98	OS	1.00	RING	0.30	0.80	0.0969	36.71	0.82	0.99	80	-1.75	0.75
SJ	M	48	4/24/98	OS	2.00	RING	0.52	0.73	0.0969	48.46	0.80	0.67	96	-1.00	1.50
SJ	M	48	5/19/98	OS	3.00	RING	0.35	0.85	0.0969	31.85	0.85	0.97	96	-2.00	0.75
SJ	M	48	7/28/98	OS	5.00	RING	0.56	1.04	0.1761	46.19	0.78	0.82	98	-2.50	2.75
SJ	M	48	12/30/97	OS	9.00	RING	0.27	0.53	0.0000	33.66	0.65	0.76	84	-3.00	2.00
SJ	M	48	11/19/98	OS	1x	xplant	0.32	0.71	0.0969	15.58	0.46	-0.12	97	-3.50	1.75
SL	F	27	10/6/97	OD	0.00	PRK	0.42	0.49	0.0000	17.52	0.25	0.39	-6.75	1.00	100
SL	F	28	1/20/98	OD	0.00	PRK	0.20	0.42	0.0000	17.43	0.31	0.48	-7.00	0.50	98
SL	F	28	9/23/97	OD	0.00	PRK	0.10	0.30	0.0000	18.60	0.21	0.43			
SL	F	28	4/14/98	OD	3.00	PRK	0.46	0.90	0.0969	57.22	0.66	-0.76	1.50		
SL	F	28	7/27/98	OD	6.00	PRK	0.30	0.54	0.0000	61.32	0.54	-0.77	1.00	0.25	80
SL	F	27	9/23/97	OS	0.00	PRK	0.50	0.25	-0.1249	14.96	0.28	0.38			
SL	F	27	10/6/97	OS	0.00	PRK	0.31	0.54	0.0000	14.74	0.29	0.34	-6.50	0.50	85
SL	F	27	11/10/97	OS	1.00	PRK	0.22	0.66	0.0000	57.32	0.67	-0.78	2.75	0.25	65

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Subj	M/F	Age	Date	Eye	Visit	Tmt	SAI	SRI	PVA Max	CVP	IAI	CEI	Sph	Cyl	X
SL	F	28	1/20/98	OS	3.00	PRK	0.15	0.43	0.0000	55.80	0.54	-0.78	0.25		
SL	F	28	4/14/98	OS	6.00	PRK	0.26	0.47	0.0000	58.86	0.55	-0.78	1.75	0.25	25
SL	F	28	7/27/98	OS	9.00	PRK	0.79	0.99	0.0969	56.79	0.58	-0.79	0.75	0.00	0
SPX	M	22	3/17/97	OD	0.00	PRK	0.39	0.41	0.0000	8.75	0.31	0.24	-5.25	0.25	180
SPX	M	23	9/29/97	OD	6.00	PRK	0.42	0.45	0.0000	34.91	0.38	-0.72	-0.25	0.50	13
SPX	M	23	1/9/98	OD	9.00	PRK	0.31	0.29	0.0000	39.57	0.32	-0.73			
SPX	M	23	3/25/98	OD	12.00	PRK	0.35	0.55	0.0000	37.07	0.39	-0.72	0.00	0.50	15
SPX	M	23	9/29/97	OS	0.00	PRK	0.31	0.34	0.0000	6.92	0.18	0.31	-6.50	0.25	172
SPX	M	23	11/7/97	OS	1.00	PRK	1.22	1.09	0.1761	49.36	0.60	-0.77	0.00		
SPX	M	23	1/9/98	OS	3.00	PRK	0.29	0.55	0.0000	43.44	0.49	-0.76	0.00	0.25	15
SPX	M	23	3/25/98	OS	6.00	PRK	0.25	0.45	0.0000	42.53	0.45	-0.74	0.00		
SPY	F	53	9/15/97	OD	0.00	PARK	0.39	0.63	0.0000	26.14	0.33	0.63	-5.50	3.00	162
SPY	F	53	10/23/97	OD	1.00	PARK	0.58	0.95	0.0969	28.42	0.55	0.52	-1.25	1.25	105
SPY	F	53	12/16/97	OD	3.00	PARK	0.30	0.42	0.0000	23 16	0.39	0.45	-1.25	0.75	140
SPY	F	53	3/16/98	OD	6.00	PARK	0.65	0.71	0.0969	24.36	0.47	0.34	-0.50	0.50	150
SPY	F	54	9/24/98	OD	12.00	PARK	0.34	0.51	0.0000	22.32	0.43	0.45	-0.75	0.75	145
SPY	F	53	9/15/97	OS	0.00	PARK	0.13	0.50	0.0000	16.14	0.30	0.55	-6.25	1.50	17
SPY	F	53	12/16/97	OS	0.00	PARK	0.18	0.62	0.0000	16.65	0.31	0.55	-6.75	1.50	15
SPY	F	53	3/16/98	OS	1.00	PARK	0.33	0.57	0.0000	21.33	0.44	-0.49	-0.75	0.25	105
SPY	F	54	9/24/98	OS	7.00	PARK	0.55	0.54	0.0000	21.09	0.37	-0.46	-0.75	0.25	75
TZ	M	47	7/31/98	OD	0.00	LASIK	0.19	0.56	0.0000	18.31	0.28	0.39			
TZ	M	47	10/2/98	OD	1.00	LASIK	0.22	0.99	0.0969	35.17	0.57	-0.71	-1.00	0.50	25
TZ	M	47	12/15/98	OD	3.00	LASIK	0.19	0.63	0.0000	33.19	0.53	-0.68	-1.50	0.75	30
TZ	M	47	7/31/98	OS	0.00	LASIK	0.50	0.83	0.0969	18.51	0.39	0.54			
TZ	M	47	10/2/98	OS	1.00	LASIK	0.27	0.98	0.0969	21.78	0.57	-0.60	-2.00	0.50	28
TZ	M	47	12/15/98	OS	3.00	LASIK	0.46	0.67	0.0969	20.69	0.32	-0.60	-2.25		
VP	M	42	12/8/97	OD	0.00	PARK	0.36	0.36	0.0000	16.16	0.24	0.49	-6.75	0.75	85
VP	M	42	1/12/98	OD	1.00	PARK							0.50	0.25	135
VP	M	42	3/16/98	OD	3.00	PARK	0.27	0.32	0.0000	30.47	0.46	-0.64	0.00	0.25	115
VP	M	43	6/29/98	OD	6.00	PARK	0.77	0.60	0.0000	31.04	0.36	-0.64	0.00		
VP	M	43	9/11/98	OD	9.00	PARK	0.25	0.45	0.0000	28.64	0.44	-0.63	-0.25	0.00	0
VP	M	42	12/8/97	OS	0.00	PRK	0.23	0.48	0.0000	17.11	0.22	0.51	-7.00	0.25	80
VP	M	42	3/16/98	OS	0.00	PRK	0.23	0.82	0.0969	16.27	0.34	0.50	-7.00	0.25	85
VP	M	43	6/29/98	OS	3.00	PRK	0.20	0.70	0.0969	39.16	0.58	-0.68	-0.50	1.00	100
VP	M	43	9/11/98	OS	6.00	PRK	0.28	0.60	0.0000	47.69	0.59	-0.69	-1.00	1.50	95
WE	F	39	6/6/97	OD	0.00	PARK	0.47	0.40	0.0000	35.44	0.35	0.55	-7.75	3.50	89
WE	F	39	10/3/97	OD	3.00	PARK	0.38	0.82	0.0969	32.22	0.53	-0.50	-0.50	1.00	42
WE	F	39	12/19/97	OD	6.00	PARK	0.49	0.87	0.0969	37.12	0.47	-0.59	-0.25	0.75	38
WE	F	39	3/13/98	OD	8.00	PARK	0.64	1.08	0.1761	33.45	0.57	-0.55	0.00	0.50	45
WE	F	40	7/17/98	OD	12.00	PARK	0.49	0.35	0.0000	38.61	0.41	-0.56	0.00		
WE	F	39	6/6/97	OS	0.00	PARK	0.37	0.64	0.0969	32.17	0.36	0.53	-7.25	2.75	89
WE	F	39	10/3/97	OS	0.00	PARK	0.48	1.24	0.1761	31.44	0.55	0.10	-7.25	2.75	89
WE	F	39	12/19/97	OS	1.50	PARK	0.85	1.12	0.1761	54.40	0.64	-0.65	1.25	1.00	75
WE	F	39	3/13/98	OS	4.00	PARK	0.73	0.56	0.0000	45.18	0.50	-0.65	1.00	0.50	28
WE	F	40	7/17/98	OS	8.00	PARK	0.47	0.63	0.0000	46.47	0.51	-0.64	1.00	0.25	035
YA	F	44	5/20/97	OD	0.00	PRK	0.35	1.08	0.1761	26.64	0.43	0.65	-14.75	0.25	85
YA	F	44	1/30/98	OD	8.00	PRK	0.91	1.15	0.1761	61.53	0.81	-0.78	-0.75	0.25	110
YA	F	44	3/3/98	OD	9.00	PRK	1.08	1.09	0.1761	63.32	0.72	-0.73	-0.75	0.50	95
YA	F	44	5/29/98	OD	12.00	PRK	0.99	1.01	0.1761	57.58	0.72	-0.71	-0.75	0.25	95
YA	F	44	5/20/97	OS	0.00	PRK	0.35	0.84	0.0969	19.44	0.26	0.53			
YA	F	44	9/18/97	OS	0.00	PRK	0.63	0.73	0.0969	23.19	0.43	0.49	-13.50	0.50	135
YA	F	44	1/30/98	OS	4.00	PRK	1.19	0.62	0.0000	85.25	0.53	-0.79	-0.75	0.50	110
YA	F	44	3/3/98	OS	5.00	PRK	1.36	0.57	0.0000	82.30	0.60	-0.80	-0.75	0.25	125
YA	F	44	5/29/98	OS	9.00	PRK	0.70	0.99	0.0969	76.10	0.51	-0.78	1.00	0.50	125

Subj	Visit	HCVA (mag)	SLCT (L) (mag)	SLCT (D) (mag)	Pupil (L)	Pupil (D)	(3.5mm) Peak	(3.5mm) Int	(5.5mm) Peak	(5.5mm) Int
AB	0.00	-0.00026	0.91746	0.17848	3.14	3.93	17902.0	429620.0	29495.0	732708.5
AB	0.00	-0.06721	1.02746	0.21848	3.14	3.93				
AB	0.00	-0.00026	1.00746	0.34848	3.14	3.93	18412.5	440250.5	30037.5	746410.5
AB	3.00	-0.12494	0.67	0.05	3.00	5.00	24953.0	498051.0	38412.0	824656.0
AB	0.00	-0.01834	0.90043	0.05426	3.14	3.93	17809.0	434714.5	29141.5	739687.0
AB	1.00	0.07918	0.41	-0.10	3.14	3.93	20731.5	445039.0	34088.0	761213.5
AB	3.00	-0.09691	0.58	0.13	3.14	3.93	19261.5	412782.0	60267.5	687815.0
AB	6.00	-0.12494	0.89	0.15	3.14	3.93	18090.5	421819.0	28998.5	713858.0
AB	9.00	-0.12494	0.79	0.06	3.00	5.00	17101.5	400960.0	26248.5	684340.5
AC	0.00	-0.03524								
AC	0.25	0.00000	0.53	-0.09	3.00	6.00	20839.5	425358.5	33769.5	710449.0
AC	1.00	0.00000	0.88	-0.10	3.00	6.00				
AC	0.00	-0.03309	0.96480	0.02488	3.00	6.00	18918.0	437223.0	29808.0	699728.5
AC	1.00	0.04139	0.34	-0.10	3.00	6.00				
AG	0.00	-0.03892	1.24789	0.54273	3.67	5.50	18170.0	407449.5	29080.0	672099.5
AG	2.00	0.00000	0.88	0.11	4.00	6.00	21015.5	408057.0	31745.5	666123.5
AG	0.00	-0.03892	1.14789	0.43273	2.90	5.21	19968.0	458565.5	32012.5	414938.0
AG	1.00	0.00000	0.59	-0.10	2.90	5.21	20947.0	422452.0	32143.0	690263.5
AG	3.00	0.02119	1.08	0.45	2.90	5.21	19315.5	405187.0	30380.0	670708.5
AG	6.00	-0.09691	1.20	0.52	4.00	6.00	18698.0	400290.5	29196.5	660067.0
AJ	15.00	0.02119	0.57	0.05	2.50	4.00	27452.5	536153.5	39407.5	829078.0
AJ	18.00	-0.04576	1.09	0.19	2.50	4.00				
AJ	0.00				3.00	4.00				
AJ	9.00	0.09691	0.14	-0.09	3.00	4.00		886341.0	84214.0	1321136.0
AJ	12.00	0.09691	0.57	-0.09	3.00	4.00				
AK	0.00									
AK	0.00	-0.16904	1.09020	0.23012	3.00	4.00	20131.0	468579.5	32786.5	791008.5
AK	1.00	-0.12494	0.85	-0.02	3.00	4.00				
AK	3.00	-0.02228	1.10	0.04	3.00	4.00				
AK	0.00	-0.03093	0.72953	0.11172	3.00	4.00	19643.5	464678.5	32340.0	788216.0
AK	1.00	0.09691	0.39	-0.10	3.00	4.00				
AK	3.00	0.09691	0.18	-0.10	3.00	4.00				
AM	0.00	-0.13284	1.12086	0.27852	2.89	4.05	19594.0	493917.5	31276.5	805618.0
AM	2.00	-0.07058	1.04	0.25	2.89	2.89	18136.0	432187.0	29104.0	702122.0
AM	5.00	0.00000	0.78	0.20	2.89	4.05	18866.5	465780.0	30566.5	776168.0
AM	8.00	0.00000	1.05	0.01	3.00	6.00	17251.5	435370.0	28181.0	730320.5
AM	0.00	-0.13434	1.08438	0.21063	2.75	4.50	19736.5	490462.5	31462.0	798852.0
AM	1.00	0.00000	0.63	-0.10	2.75	4.05	25475.5	495712.0	38852.5	807290.0
AM	3.00	-0.07058	1.04	0.34	2.75	4.05	18317.5	440058.0	29258.5	728672.0
AM	6.00	0.00000	1.08	0.25	2.75	4.50	18398.0	437798.0	29409.0	725415.5
AM	9.00	0.00000	1.04	0.41	3.00	6.00	18168.5	449446.5	29539.5	740489.5
BS	0.00				3.67	4.71				
BS	6.00	0.11394	0.36	-0.09	3.67	4.71	18977.5	390137.5	30088.5	653457.0
BS	12.00	-0.04576	0.39	-0.10	3.00	5.00	18434.5	383638.5	29596.5	647382.0
BS	16.00	-0.07058	0.65	-0.10	3.00	5.00				
BS	0.00	-0.03381	0.54656	-0.02406	3.67	4.88	18990.5	437642.5	30512.0	715160.5
BS	0.00	-0.05999	0.71887	-0.01668	3.00	5.00	19048.5	445656.5	30232.5	720694.0
BS	1.00	0.00000	0.49	-0.10	3.00	5.00				
BY	0.00				4.00	6.25				
BY	9.00	0.00000	0.39	-0.10	4.00	6.25				
BY	12.00	0.11394	0.46	-0.09	4.00	6.25	17712.0	383394.5	29130.5	686565.0
BY	18.00	0.00000	0.55	-0.09	4.00	6.50	17007.5	368901.5	28131.0	663877.0
BY	0.00	-0.04849	0.75074	0.03645	4.00	5.50				
BY	2.00	0.11394	0.29	-0.08	4.00	5.50	19403.0	415503.0	33522.5	766787.0
BY	3.00	0.02119	0.22	-0.09	4.00	5.50	19527.5	408322.0	32853.5	736152.5
CA	0.00				3.00	5.00				
CA	3.00	0.09691	0.16	-0.10	3.00	5.00	19978.5	471610.5	32193.5	811768.0
CA	6.00	0.09691	0.14	-0.10	3.00	5.00	19118.5	450257.0	30843.0	776584.5
CA	0.00				3.00	5.00				
CA	0.00	0.03539	0.61625	-0.06625	3.00	5.00	20860.5	517756.0	33813.5	879494.0
CA	3.00	0.00000	0.40	-0.08	3.00	5.00	20920.5	486967.5	34348.0	843094.0
CC	3.00	0.02119	0.63	0.25	2.75	3.85	24191.5	471083.5	37113.5	767007.0
CC	6.00	0.19033	0.57	-0.03	2.75	3.85	21327.5	445810.5	33716.5	740790.5
CC	9.00	0.00000	0.74	0.06	3.00	5.00	21327.5	445810.5	33716.5	740790.5
CC	0.00									

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Subj	Visit	HCVA (mag)	SLCT (L) (mag)	SLCT (D) (mag)	Pupil (L)	Pupil (D)	(3.5mm) Peak	(3.5mm) Int	(5.5mm) Peak	(5.5mm) Int
CC	4.00	0.20412	-0.04	-0.10	3.03	3.85	20473.5	425462.0	33133.0	723175.0
CC	7.00	0.32222	0.01	-0.09	3.03	3.85	20844.0	435086.0	33946.0	746451.5
CC	10.00	0.19033	-0.07	-0.10	3.00	5.00				
CC	10.00	0.19033	-0.07	-0.10	3.00	5.00				
CE	0.00	0.05651	0.71141	0.07484	3.58	3.66	19262.0	453228.5	30541.5	728326.0
CE	1.00	0.11394			3.58	3.66	17786.5	364925.0	28244.0	604221.0
CE	4.00	0.17609	0.35	-0.10	3.58	3.66	18410.0	390216.5	30631.0	662345.5
CE	7.00	0.13033	0.64	-0.07	3.58	3.66	18924.0	392613.0	31990.5	663342.5
CE	0.00	-0.04336	1.14844	0.21906	5.50	6.29	19813.5	455224.0	31336.0	733984.5
CE	1.00	0.02119	0.98	0.23	5.50	6.29	29438.5	504030.0	43216.0	787113.0
CE	3.00	0.00000	1.03	0.30	5.50	6.29	27195.0	478229.0	39404.0	744162.0
CE	6.00	-0.12494	1.04	0.14	5.50	6.29	26053.0	469635.0	38078.5	738096.0
CE	9.00	0.02119	1.00	0.19	5.50	6.29	22527.0	428914.5	33705.0	678978.0
CH	0.00				3.14	5.24				
CH	7.00	-0.04576	0.70	-0.01	3.14	5.24	26906.0	496493.5	40505.5	796529.0
CH	9.00	-0.12494	0.80	0.10	3.50	5.00	22201.5	421671.0	33956.5	681529.0
CH	0.00				2.90	4.63				
CH	3.00	0.00000	0.89	0.20	2.90	4.63	30680.0	557205.0	49686.5	922118.5
CH	6.00	-0.09691	0.78	0.07	3.50	5.00	28992.5	518969.5	43692.5	817796.5
CM	0.00									
CM	0.25	0.04139	0.37	-0.10	3.00	5.00	24149.0	527128.0	37751.5	864390.5
CM	1.00	0.04139	0.51	-0.04	3.00	5.00				
CM	3.00	0.02119	0.47	-0.09	4.00	7.00				
CM	0.00	-0.05139	1.02777	0.25066	3.00	5.00	22284.0	475752.5	35033.0	764889.5
CM	0.00	-0.00928	1.04602	0.28961	3.00	5.00				
CM	1.00	0.02119	0.74	-0.08	4.00	7.00				
CR	0.00	-0.16087	1.26086	0.54852	4.00	5.00	19445.0	471016.5	31397.5	766410.0
CR	0.00				4.00	5.00				
CR	0.00				4.00	5.00				
CR	3.00	-0.12494	1.03	0.18	4.00	5.00	18154.5	419107.0	29635.5	698811.5
CT	2.00	0.00000	1.04	0.23	2.50	6.00				
CT	3.00	0.00000	0.99	0.03	2.50	6.00				
CT	0.00	-0.01989	0.89395	-0.07363	2.50	6.00				
CT	0.00	-0.01989	1.15395	-0.01363	2.50	6.00				
CVP	0.00	-0.02300	0.80098	0.03059	2.41	4.13	19314.0	448130.5	31610.0	751009.5
CVP	1.00	0.00000	0.80	-0.10	2.41	4.13	17456.5	395844.0	28844.5	682081.0
CVP	3.00	0.00000	1.08	0.19	2.41	4.13	16434.5	386113.5	27062.5	656768.5
CVP	4.00	-0.04576	0.76	0.25	2.41	4.13	16644.5	403908.5	27236.5	690569.0
CVP	6.00	-0.07058	1.04	0.23	2.41	4.13	17071.0	408567.0	28116.5	700783.5
CVP	9.00	0.02119	0.94	0.13	3.00	4.00	16399.0	409639.0	27046.0	707550.5
CVP	0.00	0.02150	1.03395	0.07637	2.75	4.13	18630.5	427916.5	30678.5	727895.0
CVP	0.00	-0.00026	0.75746	0.22848	2.75	4.13	18630.5	427916.5	30678.5	727895.0
CVP	1.00	0	1.00	0.31	2.75	4.13	18479.0	430327.0	30455.5	743125.5
CVP	3.00	-0.07058	1.02	0.39	2.75	4.13	17919.0	421697.5	29357.5	725906.0
CVP	6.00	0.00000	1.04	0.20	3.00	4.00	17099.0	407181.5	27823.0	697592.5
DG	10.00	-0.15490	1.26	0.70	4.00	6.00	16066.5	383655.5	26424.0	643242.0
DG	10.00	-0.18709	1.25	0.76	4.00	6.00	15810.0	370213.0	26100.0	623613.5
DH	0.00	-0.15861	1.26559	0.52535	3.50	5.00	18847.0	441818.0	29945.5	725445.0
DH	1.00	0.00000	1.15	0.43	3.50	5.00	19039.0	412915.5	30324.5	665890.0
DH	0.00	-0.16087	1.35086	0.61852	3.50	5.00	18359.0	423651.5	29260.0	690457.5
DH	1.00	0.00000	1.15	0.46	3.50	5.00	19362.0	416918.0	30734.0	687136.0
DKX	0.00				4.46	5.35				
DKX	6.00	0.00000	1.10	0.12	4.46	5.35	22640.5	454611.0	34292.5	738890.5
DKX	9.00	-0.09691	1.03	0.14	4.46	5.35	20738.0	424989.5	32201.0	701938.0
DKX	11.00	-0.09691	1.02	0.34	4.46	5.35	19220.0	390496.5	30231.5	648302.0
DKX	12.00	0.00000	1.10	0.27	4.46	5.35				
DKX	18.00	-0.12494	0.91	0.23	3.00	5.00				
DKX	0.00	-0.06493	1.231	0.391	3.67	4.85	20176.0	482438.0	31435.5	775156.5
DKX	1.00	-0.12494	0.95	0.04	3.67	4.85	22981.5	441215.5	35444.5	725163.0
DKX	3.00	-0.12494	0.97	0.11	3.67	4.85	21058.0	429461.0	32922.0	711814.5
DKX	4.00	0.00000	0.74	-0.04	3.67	4.85				
DKX	11.00	-0.12494	0.98	0.39	3.00	5.00				
DKY	0.00				4.40	6.29				
DKY	6.00	-0.12494	1.08	0.17	4.40	6.29	17295.5	387349.5	27542.5	644628.5
DKY	9.00	0.00000	0.82	0.06	4.40	6.29	17626.0	396040.5	27859.0	658014.0

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Subj	Visit	HCVA (mag)	SLCT (L) (mag)	SLCT (D) (mag)	Pupil (L)	Pupil (D)	(3.5mm) Peak	(3.5mm) Int	(5.5mm) Peak	(5.5mm) Int
DKY	12.00	-0.12494	1.04	0.25	4.40	6.29	16665.5	380288.0	26270.0	631166.5
DS	0.00									
DS	0.25	0.06070	0.49	-0.10	4.00	6.00	20716.0	410838.5	34100.5	710713.5
DS	0.00	-0.02006	0.78160	0.03496	4.00	6.00	18708.5	447580.5	29902.5	742276.5
EO	0.00				3.25	4.50				
EO	3.00	0.00000	0.97	0.18	3.25	4.50	27220.5	525576.5	39505.0	819838.5
EO	6.00	0.00000	0.75	-0.01	3.25	4.50	25053.5	515622.5	36538.0	805952.0
EO	9.00	0.00000	0.52	-0.04	3.00	4.00				
EO	0.00				3.14	4.71				
EO	6.00	0.00000	0.80	0.05	3.14	4.71	41993.0	681914.0	59329.0	1023730.0
EO	9.00	0.04139	0.63	-0.09	3.14	4.71	36774.5	650459.5	51403.5	971758.0
EO	12.00	0.00000	1.16	0.34	3.00	4.00				
GA	0.00	-0.15178	1.240	0.366	3.00	5.00	17967.5	400725.0	28869.5	654153.0
GA	0.00				3.00	5.00				
GA	1.00	-0.07058	0.93	0.24	3.00	5.00				
GA	3.00	-0.09691	1.13	0.33	3.00	5.00	16717.0	361846.5	26968.0	302798.5
GA	4.00	-0.12494	0.99	0.24	3.00	5.00	17760.0	390877.5	28379.5	643805.5
GA	6.00	-0.12494	1.18	0.29	3.00	5.00	17461.5	372232.0	27633.5	609936.0
GA	9.00	-0.12494	1.12	0.29	3.00	5.00	17485.5	383505.5	27959.5	634695.5
GA	12.00	-0.09691	1.15	0.33	3.00	5.00	16950.0	359477.0	27230.5	596790.5
GA	0.00	-0.14328	1.330	0.394	3.00	5.00	17891.0	394266.5	28749.0	640486.5
GA	0.00				3.00	5.00				
GA	0.00	-0.14171	1.287	0.702	3.00	5.00				
GA	1.00	-0.02228	1.05	0.43	3.00	5.00	21869.5	425315.5	35114.5	699229.5
GA	3.00	-0.12494	1.26	0.38	3.00	5.00	18121.0	379106.0	29330.5	621764.5
GA	6.00	-0.12494	1.19	0.39	3.00	5.00	17081.5	373054.0	27246.5	610371.0
GA	9.00	-0.07058	1.19	0.56	3.00	5.00	15732.5	359328.0	25510.0	592465.5
GU	0.00	-0.10426	1.246	0.555	3.25	4.00	20210.0	472882.0	32364.5	770266.5
GU	0.00				3.25	4.00				
GU	1.00	0.00000	1.05	0.27	3.25	4.00	22816.5	461222.5	35011.5	745112.0
GU	3.00	-0.12494	1.20	0.65	3.25	4.00	18763.0	403871.5	29784.5	668546.0
GU	6.00	-0.12494	1.16	0.48	3.50	6.00	18442.0	423519.0	29150.0	700829.0
GU	0.00				2.75	4.40				
GU	3.00	-0.09691	1.05	0.22	2.75	4.40	19791.5	436061.0	31151.5	718824.5
GU	6.00	-0.07058	1.04	0.35	2.75	4.40	19449.0	426025.5	30153.0	696175.5
GU	9.00	-0.09691	0.96	0.37	3.50	6.00	18862.0	423986.5	29965.0	698498.5
JF	0.00	-0.04630	1.085	0.313	2.50	4.00	20873.5	475954.0	33239.0	766671.5
JF	3.00	-0.12494	1.12	0.35	2.50	4.00	24480.5	446685.0	36289.5	710269.0
JF	6.00	-0.12494	1.09	0.26	2.50	4.00	18028.0	369399.5	28120.5	606825.5
JF	0.00				2.50	4.00				
JF	3.00	-0.12494	0.68	0.04	2.50	4.00	30476.0	545802.0	44132.0	854052.5
JF	6.00	-0.12494	0.77	0.27	2.50	4.00	22361.5	436953.0	32934.0	684782.5
JF	9.00	-0.12494	1.06	0.32	2.50	4.00	18460.5	382134.5	28266.5	619155.0
JG	6.00	0.00000	1.07	0.29	3.18	4.95	17654.5	398744.0	28324.0	653092.5
JG	7.00	0.00000	1.01	0.27	3.18	4.95				
JG	9.00	0.00000	1.15	0.18	3.18	4.95				
JG	0.00	-0.01756	1.20867	0.66320	2.90	4.78	17816.5	405260.0	28376.5	660590.0
JG	1.00	0.00000	0.57	-0.08	2.90	4.78				
JG	3.00	0.00000	0.95	0.09	2.90	4.78				
JH	0.00	-0.12701	1.250	0.328	3.96	5.50	20165.0	477634.0	32565.5	782928.5
JH	1.00	0.04139	0.61	-0.03	3.96	5.50				
JH	2.00	0.02119	0.76	-0.01	3.96	5.50	24004.0	466766.5	37467.5	767884.0
JH	3.00	-0.04576	0.78	0.21	3.96	5.50	21931.0	441718.5	34311.0	730653.5
JH	6.00	0.02119	0.64	0.09	3.96	5.50	21327.5	438794.0	33576.5	727997.5
JH	9.00	0.00000	1.06	0.36	3.96	5.50	19669.5	410178.0	31486.5	688492.5
JH	12.00	0.00000	0.89	0.01	3.96	5.50	18431.5	384933.5	29891.0	654781.0
JH	0.00				3.67	5.95				
JH	3.00	0.02119	1.21	0.00	3.67	5.95	19086.5	423115.5	31653.5	720936.0
JH	6.00	0.00000	0.94	0.14	3.67	5.95	19013.5	434640.0	31327.5	737086.0
JH	9.00	0.00000	1.00	0.31	3.67	5.95	18060.5	396552.5	29899.5	676869.0
JH	12.00	0.00000	1.17	0.54	3.67	5.95	18006.0	389191.5	29345.5	664670.0
JH	17.00	-0.07058	0.98	0.35	3.67	5.95	17812.0	283921.0	29044.0	656288.0
JN	0.00				2.87	4.30				
JN	0.00	-0.04483	1.192	0.211	2.87	4.30	24666.0	542814.0	39212.0	871822.0
JN	1.00	0.11394	0.25	-0.10	2.87	4.30	42103.5	692903.0	64652.0	1105599.0

Subj	Visit	HCVA (mag)	SLCT (L) (mag)	SLCT (D) (mag)	Pupil (L)	Pupil (D)	(3.5mm) Peak	(3.5mm) Int	(5.5mm) Peak	(5.5mm) Int
JN	2.00	0.09691	-0.10	-0.10	2.87	4.30	32435.0	557070.0	50412.5	900038.0
JN	5.00	0.02119	1.01	0.12	2.87	4.30	25993.0	479125.5	39572.0	767284.5
JN	8.00	0.02119	0.99	0.22	2.87	4.30	24276.0	486089.5	37879.0	786539.5
JN	0.00				3.00	4.25				
JN	3.00	0.07918	0.05	-0.10	3.00	4.25	34198.0	595976.5	53967.5	966725.0
JN	5.00									
JN	6.00	-0.12494	0.97	0.19	3.00	4.25	33221.5	567279.0	49874.0	892145.0
JN	9.00	0.02119	0.93	0.16	3.00	4.25	32306.0	565256.5	47899.0	877667.0
JN	12.00	0.02119	0.99	0.20	3.00	4.25	31125.0	564618.0	46020.5	882493.5
JPX	6.00				4.00	7.00				
JPX	12	0.00000	0.70	0.04	4.00	7.00	24574.5	468894.5	37533.0	762957.5
JPX	0	-0.07058	1.07	0.32	4.00	7.00	19974.5	466223.0	32489.0	773688.0
JPX	0				4.00	7.00				
JR	6				5.00	7.00				
JR	12.00	-0.07058	1.27	0.68	5.00	7.00	19057.5	396962.0	29769.0	640076.5
JR	0.00				5.00	7.00				
JR	4.00	-0.07058	1.04	0.36	5.00	7.00	17372.5	394929.5	28452.5	648756.0
JRX	12.00	0.00000	0.91	0.19	4.00	7.00	31465.5	438197.5	38393.5	686654.0
JRX	9.00	0.00000	1.00	0.22	4.00	7.00	17889.0	388231.5	28185.5	629657.0
JW	0.00	-0.15134	0.702	0.025	4.00	5.00				
JW	9.00	0.02119	-0.01	-0.10	4.00	5.00				
JWX	0.00	-0.02911	1.03523	0.10914			19493.0	469010.0	31268.0	759866.0
JWX	0.00	-0.07188	0.94875	0.08125			19330.0	466140.0	30970.0	756431.0
JWX										
KA	0.00	-0.06563	0.95293	0.16176	4.00	6.50	19935.5	501510.0	31842.5	817032.5
KA	0.00									
KA	0.00	-0.06141	0.93238	0.07543	4.00	6.50	19813.5	504173.5	31758.5	823167.0
KC	0.00	0.04552	1.26777	0.51066	5.00	6.00	20993.0	469556.5	33856.0	769418.0
KC	0.00	-0.04849	1.10074	0.30645	5.00	6.00	20556.5	460352.0	32817.5	747621.0
KC	3.00									
LC	0.00				3.00	6.00				
LC	0.00				3.00	6.00				
LC	3.00	-0.12494	1.14	-0.10	3.00	6.00	26644.0	495349.0	42997.5	808333.0
LC	6.00	-0.12494	1.12	0.28	3.00	6.00	25956.5	494263.5	42246.5	805599.5
LC	0.00				3.00	6.00				
LC	6.00	-0.12494	1.07	-0.10	3.00	6.00	29341.5	527084.0	42409.0	810168.0
LC	9.00	-0.12494	0.76	-0.10	3.00	6.00	32710.0	555824.0	46634.5	836652.5
LM	0.00	-0.03743	1.084	0.281	3.44	4.13	20386.5	505291.5	32402.5	824034.5
LM	3.00	-0.12494	0.87	0.12	3.44	4.13	29146.0	529969.5	40789.0	812512.5
LM	6.00	0.00000	0.74	-0.02	3.44	4.13				
LM	9.00	-0.09691	1.00	0.25	3.44	4.13	23168.0	471464.0	33607.0	745909.5
LM	12.00	0.00000	0.97	0.35	3.44	4.81	29283.0	547713.0	41638.5	845618.5
LM	16.00	-0.12494	1.16	0.40	3.44	4.81	26763.0	502053.0	38517.0	781314.5
LM	20.00	0.00000	1.24	0.72	3.44	4.81				
LM	24.00	-0.09691	1.16	0.65	3.44	4.81	40192.0	501285.0	33928.5	790930.0
MBX	9.00				3.00	4.00				
MBX	12.00	0.00000	0.95	0.10	3.00	4.00				
MBX	18.00				3.00	4.00				
MBX	0.00				3.00	4.00				
MBX	3.00				3.00	4.00				
MBX	6.00	0.00000	0.65	-0.10	3.00	4.00				
MBX	12.00				3.00	4.00				
MBY	0.00				4.00	5.00				
MBY	0.00				4.00	5.00				
MBY	0.00	-0.04189	1.275	0.507	4.00	5.00				
MBY	0.00				4.00	5.00				
MBY	0.00				4.00	5.00				
MBY	5.00				4.00	5.00				
MBY	6.00	0.02119	0.83	-0.01	4.00	5.00				
ML	0.00				4.97	6.21				
ML	3.00	0.00000	1.00	0.12	4.97	6.21	20241.0	387972.0	31312.0	645438.5
ML	6.00	0.00000	0.48	-0.06	4.97	6.21	19136.5	387375.0	30064.0	648278.0
ML	9.00	0.00000	0.79	0.02	4.97	6.21	18084.5	374454.0	29009.0	637529.0
ML	12.00	0.04139	0.73	-0.03	4.97	6.21	16821.0	344582.5	27084.0	589373.0
ML	15.00	0.00000	0.75	0.01	4.97	6.21	16865.5	363831.0	27679.5	623501.0

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Subj	Visit	HCVA (mag)	SLCT (L) (mag)	SLCT (D) (mag)	Pupil (L)	Pupil (D)	(3.5mm) Peak	(3.5mm) Int	(5.5mm) Peak	(5.5mm) Int
ML	0.00				5.16	6.87				
ML	0.00	-0.04776	1.159	0.565	5.16	6.87	19483.0	445117.0	31316.5	730806.5
ML	1.00	0.04139	0.63	-0.10	5.16	6.87	20954.0	405830.0	32497.5	670758.5
ML	3.00	0.00000	0.59	-0.08	5.16	6.87	23531.0	443279.0	35330.5	714884.5
ML	6.00	0.00000	0.68	-0.09	5.16	6.87	20982.5	410886.0	32097.0	669052.5
ML	9.00	0.04139	0.69	-0.09	5.16	6.87	19795.0	394758.0	30229.5	644426.5
ML	12.00	0.00000	0.79	-0.05	5.16	6.87	17680.0	371009.5	27765.5	614752.0
MN	0.00				3.00	5.00				
MN	1.00	0.09691	0.07	-0.10	3.00	5.00	138176.0	1863806.0	163984.0	2181666.0
MN	3.00	0.14613	-0.10	-0.10	3.00	5.00	105170.0	1371992.0	125174.0	1686398.0
MN	0.00				3.00	5.00				
MN	0.00	-0.04410	0.72	0.02	3.00	5.00	20031.0	423702.5	32361.5	693842.0
MS	12.00	0.00000	1.00	-0.03	4.00	6.50	21389.0	391249.5	34726.0	666889.0
MS	6.00	0.09691	0.37	0.00	4.00	6.50	21943.5	382520.0	34914.0	629362.5
MSX	8.00	-0.12494	0.97	0.22	3.50	6.50	23022.0	442782.5	43818.0	810776.5
MSX	7.00	0.04139	0.46	-0.06	3.50	6.50	67771.0	952276.0	104068.0	1477987.0
PB	0.00	-0.02607	0.958	0.085	4.00	6.00	19108.0	430369.0	30250.5	695595.5
PB	1.00	-0.07058	0.34	-0.10	4.00	6.00	17994.0	383283.0	29175.5	638877.5
PB	2.00	0.02119	0.30	-0.10	4.00	6.00	16279.5	339293.0	26557.5	565903.5
PB	5.00	0.00000	0.77	0.06	4.00	6.00	16183.0	371407.5	26115.0	617773.5
PB	8.00	0.00000	0.82	0.20	4.00	6.00	16016.0	362760.5	25576.5	599439.5
PB	0.00				4.00	6.00				
PB	3.00	0.00000	-0.08	-0.10	4.00	6.00	17060.0	375457.5	27154.5	620792.0
PB	5.00	0.00000	0.47	-0.10	4.00	6.00	17151.5	387654.0	27279.0	639507.5
PB	7.00	0.04139	0.17	-0.10	4.00	6.00	16898.5	365654.0	27107.5	604672.0
PB	9.00	0.02119	0.65	0.01	4.00	6.00	16542.5	363993.5	26467.0	602182.0
PB	12.00	0.00000	0.65	-0.10	4.00	6.00	16688.5	365097.0	26344.0	598183.5
PM	12.00	0.04139	0.41	-0.03	3.14	4.71	205064.0	2432486.0	179098.0	2805260.0
PM	18.00	0.00000	0.56	0.06	3.14	4.71	184438.0	2083304.0	213566.0	2396268.0
PM	21.00	0.04139	0.70	-0.02	3.14	4.71	147916.0	1678630.0	171866.0	1985684.0
PM	0.00				2.75	4.98				
PM	0.00	-0.19679	1.225	0.507	2.75	4.98	17347.0	396492.0	27643.5	648780.0
PR	0.00	-0.07188	0.969	0.301	3.14	4.19	21086.0	509332.0	33442.0	822395.5
PR	0.00	-0.06911	0.972	0.297	3.14	4.19	21086.0	509332.0	33442.0	822395.5
PRX	1.00	0.00000	0.86	0.08	3.00	6.00	21106.0	390252.0	34441.5	675792.5
PRX	2.00	0.02119	0.64	0.03	3.00	6.00	18702.0	356094.0	30802.5	625555.0
PR	0.00	0.08120	1.001	0.291	2.90	4.95	20971.5	481200.5	33280.0	785565.5
PRX	1.00	-0.07058	0.49	-0.10	2.90	4.95	21903.0	422917.5	35214.0	714807.5
PRX	3.00	0.07918	0.90	0.20	2.90	4.95	19296.5	395815.5	31065.0	670503.5
PRX	6.00	0.00000	0.86	-0.10	2.90	4.95	18861.0	389714.5	30376.0	655390.0
PRX	7.00	0.04139	0.66	-0.10	3.00	6.00	18927.0	384842.0	30394.0	648203.5
PRX	9.00	0.00000	0.78	0.01	3.00	6.00	18649.0	383605.5	30061.5	649839.0
RL	0.00	-0.01599	0.95516	0.06109	4.00	7.00	17720.0	411998.0	28379.0	676236.5
RL	3.00	0.00000	0.50	0.07	3.00	5.00	17797.0	406525.0	28935.0	679046.0
RL	0.00	0.05355	0.38844		4.00	7.00	17796.0	409943.5	28572.5	672088.5
RL	3.00	0.02119	-0.10	-0.10	3.00	5.00	18739.0	396026.5	30222.5	665777.5
SC	0.00	0.00000	1.13	0.42	4.30	5.26	19761.0	441532.5	31675.5	717730.5
SC	6.00				4.30	5.26	20716.0	423814.5	32416.0	692516.0
SJ	0.00	-0.02067	1.30570	0.77742	3.30	4.40				
SJ	0.00	-0.14483	1.16395	0.60637	3.30	4.40				
SJ	0.00	-0.02222	1.2992	0.66953	3.30	4.40				
SJ	1.00	-0.09691	0.98	0.25	3.30	4.05	21214.0	477728.0	34359.5	792193.0
SJ	2.00	-0.12494	0.78	-0.10	3.30	4.05	21615.5	501313.5	35691.0	854705.0
SJ	3.00	0.00000	0.88	0.04	3.30	4.05				
SJ	5.00	-0.09691	0.50	-0.10	3.30	4.05				
SJ	9.00	0.02119	0.73	0.34	3.30	4.05				
SJ	1x	0.00000	1.19	0.72	3.30	4.05	20455.5	458800.0	34706.0	791927.5
SL	0.00	-0.11247	1.085	0.437	4.95	6.88	17840.5	400121.0	28418.5	646141.5
SL	0.00	-0.10950	1.118	0.283	4.95	6.88	17840.5	400121.0	28418.5	646141.5
SL	0.00				4.95	6.88				
SL	3.00	-0.12494	0.98	0.15	4.95	6.88	16760.0	355315.0	28096.5	607698.0
SL	6.00	-0.12494	0.96	0.32	4.95	6.88	16207.5	354573.0	27536.0	609351.5
SL	0.00				5.50	7.15				
SL	0.00	-0.10950	1.078	0.353	5.50	7.15	19496.0	421206.0	30531.5	674221.0
SL	1.00	0.00000	0.49	-0.10	5.50	7.15	18962.0	372941.0	30875.0	625593.0

Subj	Visit	HCVA (mag)	SLCT (L) (mag)	SLCT (D) (mag)	Pupil (L)	Pupil (D)	(3.5mm) Peak	(3.5mm) Int	(5.5mm) Peak	(5.5mm) Int
SL	3.00	-0.07058	0.99	0.38	5.50	7.15	17464.0	381128.5	28235.5	636576.5
SL	6.00	-0.12494	1.04	0.15	5.50	7.15	17527.5	369111.5	28163.0	614890.5
SL	9.00	-0.09691	0.83	0.21	5.50	7.15	16813.0	351682.0	27140.5	586507.0
SPX	0.00				2.89	3.76				
SPX	6.00	-0.12494	0.98	0.15	2.89	3.76	25272.5	484320.0	37895.5	771199.5
SPX	9.00				2.89	3.76				
SPX	12.00	-0.12494	1.05	0.36	2.89	3.76	21447.0	443011.5	32908.0	718952.0
SPX	0.00	-0.16460	1.340	0.424	2.75	4.68	18563.5	446024.0	29481.0	725509.0
SPX	1.00	-0.07058	0.96	0.27	2.75	4.68	29128.0	533610.5	44287.5	849152.0
SPX	3.00	-0.12494	1.00	0.33	2.75	4.68	27205.0	517482.5	42901.5	845770.5
SPX	6.00	-0.12494	1.07	0.43	2.75	4.68	24699.0	497197.5	39511.5	819049.5
SPY	0.00	-0.00412	1.086	0.214	4.58	5.81	19274.5	434923.5	30550.0	703234.0
SPY	1.00	0.00000	0.96	0.12	4.58	5.81				
SPY	3.00	0.00000	1.06	0.35	4.58	5.81	20600.0	225744.5	34101.5	691090.0
SPY	6.00	0.02119	1.01	0.22	4.58	5.81	21597.5	446359.5	34385.5	732968.5
SPY	12.00	-0.07058	1.08	0.35	4.00	6.00	18023.0	402201.0	28875.0	664108.0
SPY	0.00	-0.03743	1.114	0.311	3.67	5.50	18546.0	411109.0	29489.5	667046.5
SPY	0.00	0.00696	1.047	0.196	3.67	5.50	18546.0	411109.0	29489.5	667046.5
SPY	1.00	0.02119	1.13	0.30	3.67	5.50	20350.5	423594.5	32992.5	709855.5
SPY	7.00	-0.02228	1.06	0.25	4.00	6.00	16282.5	333121.0	26567.5	565662.5
TZ	0.00									
TZ	1.00	0.00000	0.80	-0.06	5.00	7.50	18413.0	369320.5	29909.0	620137.5
TZ	3.00	-0.04576	0.94	0.09	5.00	7.50				
TZ	0.00									
TZ	1.00	0.00000	0.75	0.06	5.00	7.00	18114.0	368691.0	29253.5	609765.5
TZ	3.00	-0.07058	0.92	0.26	5.00	7.00				
VP	0.00	-0.13657	1.100	0.464	3.50	5.50	17896.0	399225.0	28422.5	655259.5
VP	1.00	0.00000	0.84	-0.02	3.50	5.50	19048.5	351195.0	30169.5	593004.5
VP	3.00	0.02119	1.01	0.45	3.50	5.50	17261.5	345768.0	27073.0	577995.0
VP	6.00	-0.04576	1.05	0.21	4.00	6.00	17292.5	355243.5	27403.0	597151.0
VP	9.00	0.00000	1.06	0.28	3.50	5.50				
VP	0.00	-0.11321	1.277	0.448	3.50	5.50	17733.0	383818.5	28114.5	626091.0
VP	0.00	-0.16756	1.297	0.508	3.50	5.50	17733.0	383818.5	28114.5	626091.0
VP	3.00	0.00000	1.02	0.13	4.00	6.00	18018.0	349520.0	28557.5	585927.0
VP	6.00	0.00000	1.13	0.56	3.00	5.00				
WE	0.00				4.08	5.89				
WE	3.00	0.00000	0.78	0.06	4.08	5.89	19522.0	448296.0	30741.5	738724.0
WE	6.00	-0.12494	1.06	0.18	4.08	5.89	18776.0	412150.5	29735.0	691350.0
WE	8.00	-0.02228	1.19	0.30	4.08	5.89	18162.5	414440.5	28772.0	694403.5
WE	12.00	-0.12494	1.12	0.37	3.00	5.50	17534.5	395012.0	27692.0	661272.0
WE	0.00				4.08	5.89				
WE	0.00	-0.03668	1.093	0.190	4.08	5.89	23917.5	566867.0	38405.0	929458.5
WE	1.50	-0.12494	1.06	0.17	4.08	5.89	33687.0	586684.5	46326.0	892321.0
WE	4.00	0.02119	1.19	0.30	4.08	5.89	25646.5	496005.5	36991.5	787301.0
WE	8.00	-0.12494	1.14	0.37	3.00	5.50	21344.0	430414.5	31903.5	702764.0
YA	0.00				2.00	3.00				
YA	8.00	0.00000	0.76	-0.06	2.00	3.00	33870.0	591785.5	47929.0	913185.5
YA	9.00	0.04139	0.87	0.11	2.00	3.00				
YA	12.00	0.04139	0.85	-0.10	2.00	3.00	28081.0	542964.0	41593.0	875692.0
YA	0.00				2.20	3.41				
YA	0.00				2.20	3.41				
YA	4.00	-0.07058	1.03	0.13	2.20	3.41	23640.5	515350.0	39529.5	905933.0
YA	5.00	0.02119	1.09	0.18	2.20	3.41				
YA	9.00	0.04139	0.95	-0.10	2.20	3.41	23313.0	468679.0	36155.0	817746.0

Subj	Visit	TMS pupil	pupilx	pupily	EOZ 1 area	EOZ 1 radius	EOZ 2 area	EOZ 2 radius	EOZ dc
AB	0.00	3.15	-0.2431	0.0071	8.3682	1.6321	22.1326	2.6542	0.7451
AB	0.00	3.15	-0.0248	-0.0107	7.3931	1.5340	16.5527	2.2954	0.2548
AB	0.00	3.15	-0.1121	0.0028	8.8969	1.6828	19.0616	2.4632	0.3694
AB	3.00	3. 7	-0.0648	-0.0096	12.9539	2.0306	20.4106	2.5489	0.5324
AB	0.00	3.13	0.1612	0.0992	8.6608	1.6604	18.7115	2.4405	0.4323
AB	1.00	3.13	-0.0931	0.1141	5.4728	1.3199	11.4799	1.9116	0.2307
AB	3.00	3.13	0.0274	0.0721	5.4130	1.3126	11.8649	1.9434	0.0364
AB	6.00	3.13	0.0274	0.0721	5.5213	1.3257	13.5436	2.0763	0.0568
AB	9.00	3.13	0.0274	0.0721	4.7449	1.2290	14.8847	2.1767	0.5087
AC	0.00		0.3063	0.1549	7.4732	1.5423	17.5704	2.3649	0.3401
AC	0.25		0.2242	0.1045	6.4859	1.4368	12.5210	1.9964	0.6204
AC	1.00	3.28	0.2242	0.1045	6.8471	1.4763	12.7839	2.0172	0.5892
AC	0.00		-0.0626	0.0864	10.8722	1.8603	21.6725	2.6265	0.3716
AC	1.00	3.43	-0.0626	0.0864	5.9775	1.3794	11.6595	1.9265	0.4176
AG	0.00	3.64	0.0368	0.0922	8.0677	1.6025	16.6501	2.3021	0.2026
AG	2.00	3.61	0.0520	0.0613	6.0597	1.3888	10.9786	1.8694	0.5322
AG	0.00	3.20	-0.0230	0.0265	8.9970	1.6923	18.9551	2.4563	0.4299
AG	1.00	3.46	-0.0420	0.0127	5.3201	1.3013	9.2569	1.7166	0.2562
AG	3.00	3.30	-0.0896	-0.0225	9.4362	1.7331	14.0089	2.1117	0.2389
AG	6.00	3.23	-0.0841	-0.0060	7.2855	1.5228	12.0332	1.9571	0.2470
AJ	15.00		0.0000	0.0000	7.0384	1.4968	13.6771	2.0865	0.2334
AJ	18.00		0.0000	0.0000	7.7465	1.5703	14.6835	2.1619	0.3908
AJ	0.00		0.0000	0.0000	8.0681	1.6025	15.7286	2.2375	0.5423
AJ	9.00		0.0000	0.0000	4.7389	1.2282	10.2534	1.8066	1.1712
AJ	12.00		0.0000	0.0000	5.2859	1.2971	10.9047	1.8631	1.1552
AK	0.00		-0.2917	-0.2226	7.3051	1.5249	19.4663	2.4892	0.9728
AK	0.00		-0.2917	-0.2226	9.2766	1.7184	18.6022	2.4334	0.6753
AK	1.00		-0.2917	-0.2226	5.8368	1.3631	11.8489	1.9421	0.8758
AK	3.00		-0.2917	-0.2226	9.0474	1.6970	14.9868	2.1841	0.4792
AK	0.00		0.1760	0.1136	8.5130	1.6461	23.0366	2.7079	0.1888
AK	1.00		0.1760	0.1136	4.6475	1.2163	8.8321	1.6767	0.3856
AK	3.00		0.1760	0.1136	5.9577	1.3771	11.3334	1.8994	0.3570
AM	0.00								
AM	2.00	3.20	-0.0844	0.1645	6.1855	1.4032	11.1852	1.8869	0.2200
AM	5.00	3.98	-0.2350	0.2000	9.3297	1.7233	15.2073	2.2001	0.1584
AM	8.00	4.78	-0.2696	0.2039	8.6333	1.6577	14.7827	2.1692	0.2070
AM	0.00								
AM	1.00	3.18	-0.2760	-0.0230	5.2808	1.2965	11.4341	1.9078	0.7000
AM	3.00	2.88	-0.2887	-0.0488	7.3163	1.5261	14.7610	2.1676	0.4912
AM	6.00	3.35	-0.2202	0.0257	8.9401	1.6869	15.2397	2.2025	0.2095
AM	9.00	3.79	-0.1831	0.0522	9.3981	1.7296	16.7186	2.3069	0.3626
BS	0.00	3.10	-0.2047	0.1646	9.3116	1.7216	17.2911	2.3460	0.1864
BS	6.00		-0.3464	0.1011	2.8218	0.9477	6.1102	1.3946	0.3911
BS	12.00		-0.2952	0.0809	4.3000	1.1699	8.7827	1.6720	0.4177
BS	16.00	3. 4	-0.2846	0.1421	4.0955	1.1418	7.9954	1.5953	0.5376
BS	0.00		0.3136	0.0962	9.5305	1.7417	16.1043	2.2641	0.2651
BS	0.00		0.1052	0.0676	8.1237	1.6081	16.1212	2.2653	0.2608
BS	1.00	3.36	0.1905	0.0806	7.9684	1.5926	14.3340	2.1360	0.3609
BY	0.00	4.20	0.0011	0.0710	8.2638	1.6219	28.9550	3.0359	0.5375
BY	9.00	4.20	0.0011	0.0710	3.3080	1.0261	7.3093	1.5253	0.4545
BY	12.00	4.20	0.0011	0.0710	0.0000	0.0000	6.0059	1.3827	0.4963
BY	18.00	3.70	-0.0197	0.0817	5.8830	1.3684	11.9646	1.9515	0.3930
BY	0.00	4.20	-0.1102	0.1763	14.3189	2.1349	28.8225	3.0289	1.2027
BY	2.00	3.48	-0.0954	0.1336	6.3998	1.4273	11.3465	1.9004	0.2530
BY	3.00	3.62	-0.1010	0.1144	4.9974	1.2612	9.2739	1.7181	0.2796
CA	0.00	3.28	-0.1737	0.0315	6.4255	1.4301	14.0285	2.1132	0.3575
CA	3.00	3.13	-0.2300	0.0244	6.3779	1.4248	13.5576	2.0774	0.4799
CA	6.00	3.30	-0.2096	0.0318	5.8439	1.3639	12.4905	1.9940	0.7342
CA	0.00		0.1777	0.0290	8.5814	1.6527	17.2230	2.3414	0.3228
CA	0.00	3. 2	0.2277	0.0317	7.2502	1.5191	14.1086	2.1192	0.4130
CA	3.00	3.28	0.1233	-0.0042	7.9903	1.5948	14.8484	2.1740	0.1610
CC	3.00	2.73	-0.4373	-0.0088	2.3931	0.8728	4.8727	1.2454	0.9409
CC	6.00	2.36	-0.4118	0.1444	3.5817	1.0678	6.9884	1.4915	0.8304
CC	9.00	2.43	-0.4710	0.0887	3.3337	1.0301	6.5958	1.4490	0.7464
CC	0.00	2.51	0.4212	0.0133	11.2604	1.8932	19.2764	2.4771	0.6468

Subj	Visit	TMS pupil	pupilx	pupily	EOZ 1 area	EOZ 1 radius	EOZ 2 area	EOZ 2 radius	EOZ dc
CC	4.00	2.94	0.4212	0.0133	3.5798	1.0675	6.7528	1.4661	0.1619
CC	7.00	2.94	0.4212	0.0133	2.4486	0.8828	5.0188	1.2639	0.5755
CC	10.00	2.94	0.4212	0.0133	1.1383	0.6019	2.2933	0.8544	0.9000
CC	10.00	2.94	0.4212	0.0133	3.0256	0.9814	6.7730	1.4683	0.3373
CE	0.00		0.4212	0.0133	2.2382	0.8441	5.9856	1.3803	0.3373
CE	1.00	4.15	-0.1256	0.1104	4.3114	1.1715	7.7497	1.5706	0.1890
CE	4.00	4.28	0.1316	0.3272	16.9933	2.3258	20.4316	2.5502	0.1519
CE	7.00	3.69	0.0985	0.3449	6.4664	1.4347	10.7347	1.8485	0.1129
CE	0.00		0.0902	0.2590	23.8119	2.7531	28.5761	3.0160	0.1222
CE	1.00								
CE	3.00	3.62	-0.0835	0.0397	5.4016	1.3113	15.0129	2.1860	0.2755
CE	6.00	3.54	-0.0443	0.0385	10.3882	1.8184	16.1115	2.2646	0.8542
CE	9.00	3.57	-0.1025	-0.0134	11.9415	1.9496	17.4742	2.3584	0.7351
CH	0.00		0.0378	0.0658	9.0953	1.7015	15.6225	2.2300	1.0297
CH	7.00	3.62	0.0378	0.0658	4.8402	1.2412	8.9857	1.6912	0.2817
CH	9.00	3.59	0.0509	0.0626	6.6565	1.4556	11.4277	1.9072	0.3707
CH	0.00	3.49	-0.0414	0.1359	10.4963	1.8279	19.3709	2.4831	0.2752
CH	3.00	3.70	-0.0414	0.1359	4.7992	1.2360	10.7907	1.8533	0.2488
CH	6.00	3.70	-0.0551	-0.0131	10.1731	1.7995	15.8841	2.2486	0.2562
CM	0.00		-0.2206	0.2976	11.5129	1.9143	21.8414	2.6367	0.2837
CM	0.25		-0.2025	0.1610	5.3802	1.3087	10.2687	1.8079	0.7462
CM	1.00	3.23	-0.2025	0.1610	6.9451	1.4868	12.3752	1.9847	0.5657
CM	3.00		-0.3693	0.3195	9.1123	1.7031	14.3363	2.1362	0.3525
CM	0.00	3.72	0.2603	0.2188	7.4015	1.5349	16.2545	2.2746	0.5130
CM	0.00	3.72							
CM	1.00		0.2235	0.3329	7.4205	1.5369	11.7416	1.9333	0.4738
CR	0.00	4.12	-0.3824	0.2441	12.6335	2.0053	23.5928	2.7404	0.3860
CR	0.00		0.2301	0.2128	27.1568	2.9401	46.7225	3.8565	0.3796
CR	0.00	4.16	0.2300	0.2472	8.9401	1.6869	19.0319	2.4613	0.2283
CR	3.00	3.59	0.1219	0.1618	7.5167	1.5468	12.9412	2.0296	0.1613
CT	2.00	3.30	-0.3010	-0.0934	18.5014	2.4268	31.3699	3.1600	0.3700
CT	3.00	3.22	-0.2760	-0.0265	13.2691	2.0552	19.0699	2.4638	
CT	0.00	2.98	0.2907	-0.0889	10.0542	1.7890	18.5810	2.4320	0.3877
CT	0.00	3.49	0.3747	-0.1785	7.3042	1.5248	15.7074	2.2360	0.2973
CVP	0.00		-0.1984	0.0679	15.4326	2.2164	33.2868	3.2551	0.6627
CVP	1.00	2.89	0.1172	0.1977	5.4223	1.3138	11.8041	1.9384	0.5213
CVP	3.00	2.73	0.0788	0.2296	8.8443	1.6779	17.7736	2.3786	0.4864
CVP	4.00	2.91	0.1653	0.2053	5.4412	1.3161	12.2360	1.9735	0.5210
CVP	6.00		-0.1766	-0.0094	6.3500	1.4217	18.0744	2.3986	0.5445
CVP	9.00	3.9	0.1179	0.1721	5.9206	1.3728	13.2784	2.0559	0.5813
CVP	0.00		0.1838	-0.0088	13.0701	2.0397	28.5692	3.0156	0.4318
CVP	0.00	2.81	-0.0273	0.0312	11.2652	1.8936	24.2407	2.7778	0.3975
CVP	1.00	2.86	-0.0204	0.0067	12.2108	1.9715	21.1922	2.5972	0.2447
CVP	3.00	2.39	-0.0387	-0.0125	12.6416	2.0060	22.6448	2.6848	0.2650
CVP	6.00	2.81	0.0130	0.1016	6.4381	1.4315	13.8869	2.1025	0.8651
DG	10.00	3.36	-0.4466	0.0309	10.5063	1.8287	15.8903	2.2490	0.4074
DG	10.00	3.12	0.2906	0.1310	7.3839	1.5331	14.6351	2.1584	0.6597
DH	0.00		-0.0965	-0.0940	7.5682	1.5521	16.7623	2.3099	0.2443
DH	1.00	3.20	-0.1043	-0.1130	9.7986	1.7661	16.7263	2.3074	0.3846
DH	0.00		0.1087	-0.0260	9.7241	1.7593	19.9783	2.5218	0.2575
DH	1.00	3.12	0.0838	-0.0048	7.1761	1.5114	14.6542	2.1598	0.4002
DKX	0.00	3.68	-0.0820	0.1473	7.8160	1.5773	15.9923	2.2562	0.0816
DKX	6.00	3.78	-0.0755	-0.0126	7.6189	1.5573	12.5204	1.9963	0.2430
DKX	9.00	3.72	-0.0450	0.0268	7.1157	1.5050	11.3430	1.9002	0.2946
DKX	11.00	3.67	-0.0683	-0.0133	6.0262	1.3850	9.6299	1.7508	0.0881
DKX	12.00	3.64	-0.0776	-0.0235	4.6986	1.2230	8.2091	1.6165	0.1183
DKX	18.00	3.96	-0.1161	-0.0951	5.6743	1.3439	10.7422	1.8491	0.2288
DKX	0.00	4.69	0.1221	-0.0649	8.8224	1.6758	17.4404	2.3562	0.2389
DKX	1.00	3.88	0.0007	0.1760	1.4950	0.6898	2.9486	0.9688	0.2109
DKX	3.00	3.80	0.0655	-0.0451	4.9196	1.2514	8.5173	1.6466	0.1327
DKX	4.00	4.27	0.0170	-0.0217	3.9163	1.1165	7.0489	1.4979	0.1817
DKX	11.00	3.78	0.0571	-0.1420	5.3315	1.3027	8.9308	1.6860	0.1295
DKY	0.00	4.93	-0.2790	-0.1308	6.4245	1.4300	13.4850	2.0718	0.3278
DKY	6.00	4.90	-0.2190	0.1107	5.5671	1.3312	11.2825	1.8951	0.3695
DKY	9.00	3.72	-0.2190	0.1107	5.2032	1.2869	11.2139	1.8893	0.1459

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Subj	Visit	TMS pupil	pupilx	pupily	EOZ 1 area	EOZ 1 radius	EOZ 2 area	EOZ 2 radius	EOZ dc
DKY	12.00	3.75	-0.2506	0.1660	4.4212	1.1863	10.1407	1.7966	0.5620
DS	0.00		-0.1463	0.0430	9.6417	1.7519	19.6524	2.5011	0.4877
DS	0.25		-0.1463	0.0430	0.6340	0.4492	1.3486	0.6552	1.0658
DS	0.00		0.1463	0.0430	10.6388	1.8402	20.9328	2.5813	0.3293
EO	0.00	4.85	-0.0847	-0.0372	8.9334	1.6863	16.8766	2.3178	0.0815
EO	3.00		-0.0848	0.0020	11.8953	1.9459	18.9672	2.4571	0.5290
EO	6.00	3.75	0.0275	-0.0201	6.1727	1.4017	12.2934	1.9782	0.1981
EO	9.00	3.75	0.0726	-0.0320	6.4962	1.4380	13.1027	2.0422	0.0681
EO	0.00	4.41	0.0426	-0.2133	8.1558	1.6112	15.8433	2.2457	0.2469
EO	6.00		0.0412	-0.0309	6.9979	1.4925	11.8295	1.9405	0.5746
EO	9.00	3.91	0.0063	-0.2765	9.4564	1.7350	15.8492	2.2461	0.2424
EO	12.00	4.34	0.0012	-0.2619	8.1043	1.6061	15.4933	2.2207	0.2567
GA	0.00	3.99	-0.2528	0.2199	12.6880	2.0097	24.5080	2.7931	0.2114
GA	0.00		-0.2077	0.2031	12.9470	2.0301	24.3997	2.7869	0.1457
GA	1.00	4.6	-0.2470	0.1737	9.2518	1.7161	15.7190	2.2369	0.0614
GA	3.00	4.9	-0.2189	0.2259	9.8172	1.7677	16.5783	2.2972	0.0688
GA	4.00	4.30	-0.2952	0.2317	7.0950	1.5028	13.8432	2.0991	0.3332
GA	6.00	3.46	-0.1730	0.1199	8.9160	1.6847	16.1929	2.2703	0.1700
GA	9.00	3.83	-0.1737	0.1592	9.6340	1.7512	16.9222	2.3209	0.2100
GA	12.00	3.46	-0.1672	0.1578	8.0979	1.6055	15.1386	2.1952	0.0781
GA	0.00	4.13	0.3890	0.1381	11.1401	1.8831	24.0820	2.7687	0.0418
GA	0.00		0.4484	0.1844	12.1422	1.9660	24.6247	2.7997	0.0871
GA	0.00	4.4	0.3900	0.1406	12.5264	1.9968	24.8935	2.8149	0.1861
GA	1.00	4.56	0.4490	0.0770	9.4622	1.7355	18.3622	2.4176	0.4230
GA	3.00	3.91	0.3744	0.1307	11.0872	1.8786	19.6489	2.5009	0.3671
GA	6.00	3.91	0.3616	0.1781	9.6219	1.7501	19.3549	2.4821	0.2341
GA	9.00	3.65	0.3101	0.0887	10.8422	1.8577	19.9718	2.5214	0.2549
GU	0.00	3.49	0.0155	0.0110	9.3071	1.7212	18.4540	2.4237	0.1974
GU	0.00		-0.0432	0.1692	7.3307	1.5276	16.0405	2.2596	0.3077
GU	1.00	3.36	-0.0328	0.1037	4.0637	1.1373	8.8886	1.6821	0.5781
GU	3.00	3.51	-0.0713	0.0847	4.8172	1.2383	10.6882	1.8445	0.5318
GU	6.00	3.33	-0.0678	0.1116	5.1929	1.2857	10.4569	1.8244	0.2238
GU	0.00		-0.1277	-0.2605	9.6483	1.7525	18.5373	2.4291	0.3246
GU	3.00	3.59	0.0278	0.0536	5.6607	1.3423	9.9673	1.7812	0.0856
GU	6.00	3.54	0.0383	0.0656	5.1995	1.2865	10.1373	1.7963	0.1570
GU	9.00	3.25	0.0259	0.1149	5.7305	1.3506	10.8464	1.8581	0.3531
JF	0.00	2.63	-0.1698	0.0652	5.6085	1.3361	13.1319	2.0445	0.0543
JF	3.00	2.78	-0.1081	0.0823	3.5138	1.0576	7.8559	1.5813	0.6510
JF	6.00	3.4	-0.0973	-0.0434	3.8712	1.1101	9.0518	1.6974	0.8350
JF	0.00		0.1081	0.0823	8.1967	1.6153	16.9665	2.3239	0.1148
JF	3.00		0.1081	0.0823	5.8205	1.3611	10.4944	1.8277	0.7575
JF	6.00		0.1081	0.0823	4.7440	1.2288	9.7538	1.7620	0.2899
JF	9.00		0.1081	0.0823	4.7863	1.2343	11.3456	1.9004	0.2649
JG	6.00	3.51	-0.1745	0.1742	6.3764	1.4247	16.8327	2.3147	0.8259
JG	7.00	3.49	-0.1966	0.2033	4.8975	1.2486	16.0775	2.2622	1.7164
JG	9.00	3.14	-0.1935	0.1693	8.4035	1.6355	19.7789	2.5091	0.7885
JG	0.00	4.25	0.3404	0.1713	10.0430	1.7880	20.8889	2.5786	0.5307
JG	1.00	3.99	0.3081	0.2212	8.9918	1.6918	21.3505	2.6069	2.0310
JG	3.00	3.54	0.1664	0.1482	5.4143	1.3128	11.6941	1.9293	0.3338
JH	0.00	3.9	0.1929	0.0699	9.6446	1.7521	19.2225	2.4736	0.3319
JH	1.00	3.2	0.3652	0.0874	4.1813	1.1537	7.8647	1.5822	0.0781
JH	2.00	3.17	0.3461	0.0543	7.4245	1.5373	11.4767	1.9113	0.0844
JH	3.00	3.7	0.3379	0.0781	6.8498	1.4766	10.9569	1.8675	0.0927
JH	6.00	3.44	0.2663	0.0656	7.9276	1.5885	12.3601	1.9835	0.2932
JH	9.00	3.51	0.2440	0.1005	7.1446	1.5080	12.5769	2.0008	0.2769
JH	12.00	3.38	0.3255	0.1167	7.6778	1.5633	12.0418	1.9578	0.1850
JH	0.00		-0.2553	-0.4656	8.1037	1.6061	18.3279	2.4154	0.5799
JH	3.00	2.88	-0.1596	0.1227	5.5019	1.3234	10.4901	1.8273	0.4277
JH	6.00		-0.0658	0.0447	5.7964	1.3583	10.8280	1.8565	0.4207
JH	9.00		-0.0658	0.0447	5.7663	1.3548	10.7060	1.8460	0.3733
JH	12.00	3.15	-0.1819	0.1651	5.2921	1.2979	10.2421	1.8056	0.3438
JH	17.00	3.25	-0.1489	0.1298	5.7733	1.3556	10.7966	1.8538	0.2328
JN	0.00		-0.0150	0.1478	6.5903	1.4484	14.1728	2.1240	0.2206
JN	0.00	3.7	-0.0417	0.0181	7.8157	1.5773	16.4911	2.2911	0.1124
JN	1.00	3.14	-0.0150	0.1478	8.8055	1.6742	14.3696	2.1387	0.4515

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Subj	Visit	TMS pupil	pupilx	pupily	EOZ 1 area	EOZ 1 radius	EOZ 2 area	EOZ 2 radius	EOZ dc
JN	2.00	3.38	-0.0557	0.2856	7.4774	1.5428	12.7324	2.0132	0.5179
JN	5.00	2.88	-0.0777	0.0391	9.0832	1.7004	15.1129	2.1933	0.4132
JN	8.00	2.98	-0.0114	-0.0163	7.8399	1.5797	14.6696	2.1609	0.2688
JN	0.00	3. 7	0.0096	-0.0081	8.9435	1.6872	18.1209	2.4017	0.1168
JN	3.00	3.44	-0.0297	0.0584	6.2089	1.4058	11.2553	1.8928	0.9049
JN	5.00		-0.0297	0.0584	7.8822	1.5840	13.1066	2.0425	0.8006
JN	6.00		-0.0297	0.0584	7.1774	1.5115	12.1378	1.9656	0.8530
JN	9.00		-0.0525	-0.1753	7.1873	1.5125	12.0715	1.9602	0.6460
JN	12.00	2.65	-0.0694	-0.0993	7.3959	1.5343	12.5887	2.0018	0.5681
JPX	6.00		-0.0979	-0.0344	7.8521	1.5809	15.1495	2.1960	0.3223
JPX	12		-0.0979	-0.0344	6.7234	1.4629	13.8507	2.0997	0.4522
JPX	0		0.3995	0.0449	11.3945	1.9045	26.2365	2.8899	0.8177
JPX	0		0.3995	0.0449	12.7018	2.0107	28.0695	2.9891	0.7994
JR	6		-0.0854	-0.2101	6.7494	1.4657	13.6504	2.0845	0.1877
JR	12.00	3.70	0.0353	-0.1276	7.3886	1.5336	14.5037	2.1486	0.0488
JR	0.00	4.67	0.2340	-0.0777	5.1434	1.2795	11.6138	1.9227	0.0433
JR	4.00	4.33	0.1787	-0.1732	6.6782	1.4580	13.2650	2.0548	0.2692
JRX	12.00	3.44	-0.4486	0.1053	9.6102	1.7490	14.8397	2.1734	0.2294
JRX	9.00	3.39	0.2585	0.1400	7.6878	1.5643	13.8267	2.0979	0.2482
JW	0.00		0.0000	0.0000	8.7991	1.6736	17.6178	2.3681	0.4714
JW	9.00	3.14	-0.0991	0.4456	4.7270	1.2266	8.5139	1.6462	1.4786
JWX	0.00	3.70	0.2620	0.1652	7.4145	1.5363	15.1785	2.1981	0.1604
JWX	0.00	4.43	-0.2620	0.1652	8.8756	1.6808	16.4080	2.2854	0.2572
JWX			-0.2620	0.1652	6.4798	1.4362	12.9890	2.0334	0.9863
KA	0.00		-0.4809	-0.1317	7.1369	1.5072	15.3611	2.2112	0.3004
KA	0.00	4.69	0.2610	-0.0877	6.5981	1.4492	14.5908	2.1551	0.1035
KA	0.00	5.24	0.3840	0.3444	6.9756	1.4901	15.0150	2.1862	0.3471
KC	0.00	4.87	0.0833	0.0806	13.3130	2.0586	25.2103	2.8328	0.1315
KC	0.00		0.2392	0.2371	11.2439	1.8918	23.9760	2.7626	0.1891
KC	3.00	3.10	0.2558	0.3135	6.0086	1.3830	11.8267	1.9402	0.5431
LC	0.00	3.10	-0.2321	-0.2215	3.2467	1.0166	8.0740	1.6031	0.3561
LC	0.00		-0.1327	0.0132	10.8677	1.8599	20.4636	2.5522	0.1185
LC	3.00	3. 9	-0.0882	-0.0017	7.9892	1.5947	17.4391	2.3561	0.1139
LC	6.00		-0.1176	0.0052	4.5144	1.1987	8.4296	1.6381	0.3495
LC	0.00	3.36	0.0513	0.0367	8.3379	1.6291	17.1161	2.3341	0.3864
LC	6.00	3.28	0.0913	-0.3095	5.6290	1.3386	10.6447	1.8407	0.4681
LC	9.00		0.0913	-0.3095	5.3833	1.3090	10.4176	1.8210	0.5795
LM	0.00		-0.3484	-0.0612	8.8311	1.6766	17.1465	2.3362	0.3781
LM	3.00	3.38	-0.0737	0.0332	7.0053	1.4933	12.6408	2.0059	0.6450
LM	6.00	2.78	-0.1066	0.0555	7.3156	1.5260	12.9376	2.0293	0.7474
LM	9.00		-0.2996	0.0053	6.7741	1.4684	13.0370	2.0371	0.9777
LM	12.00		0.0830	0.0164	7.4666	1.5417	14.5901	2.1550	0.4075
LM	16.00	3.28	0.0830	0.0164	6.8213	1.4735	13.7321	2.0907	0.4724
LM	20.00	3.38	0.1070	0.0059	8.4652	1.6415	14.9051	2.1782	0.3585
LM	24.00		0.3562	-0.0041	9.1426	1.7059	15.9887	2.2560	0.5962
MBX	9.00		-0.0215	0.1811	6.4448	1.4323	11.0686	1.8770	0.1145
MBX	12.00	3.62	0.0089	0.0985	7.4054	1.5353	12.3188	1.9802	0.2337
MBX	18.00		0.0119	0.1102	4.9247	1.2520	9.3268	1.7230	0.3907
MBX	0.00		-0.0225	0.1063	8.1662	1.6123	18.0703	2.3983	0.4848
MBX	3.00		0.1108	0.0931	4.6776	1.2202	8.0488	1.6006	0.3959
MBX	6.00	3.54	-0.0325	0.0461	2.5290	0.8972	4.7637	1.2314	0.5419
MBX	12.00		-0.0225	0.1063	3.7516	1.0928	7.6524	1.5607	0.7038
MBY	0.00		-0.2525	0.2023	12.0955	1.9622	24.9325	2.8171	0.4024
MBY	0.00		-0.1762	0.0592	9.2225	1.7134	18.5443	2.4296	0.2644
MBY	0.00	3.93	0.0643	-0.1043	9.4995	1.7389	19.4992	2.4913	0.6252
MBY	0.00		0.0748	0.1597	7.1207	1.5055	15.0601	2.1895	0.1308
MBY	0.00		0.0748	0.1597	7.7802	1.5737	16.3757	2.2831	0.3196
MBY	5.00		0.0327	0.2113	3.6124	1.0723	7.0566	1.4987	0.2290
MBY	6.00	3.57	0.0327	0.2113	4.6424	1.2156	8.8212	1.6757	0.4572
ML	0.00	4.52	-0.1652	0.3664	6.3757	1.4246	15.3103	2.2076	0.2571
ML	3.00	4.82	-0.1652	0.3664	5.1003	1.2742	10.4880	1.8271	0.4882
ML	6.00	4.22	-0.2123	0.3529	3.9581	1.1225	8.5248	1.6473	0.7761
ML	9.00	4.11	-0.1765	0.3780	2.9759	0.9733	6.4633	1.4343	0.8063
ML	12.00	4.64	-0.1839	0.3686	4.1786	1.1533	8.6711	1.6614	0.7334
ML	15.00	5.51	-0.1378	0.3775	4.1354	1.1473	9.1847	1.7098	0.5109

Subj	Visit	TMS pupil	pupilx	pupily	EOZ 1 area	EOZ 1 radius	EOZ 2 area	EOZ 2 radius	EOZ dc
ML	0.00		-0.0341	0.1302	9.2608	1.7169	18.8511	2.4496	0.1389
ML	0.00	5.19	-0.0168	0.1551	8.9189	1.6849	17.8351	2.3827	0.1665
ML	1.00	3.91	0.0229	0.0912	1.8529	0.7680	3.9440	1.1205	0.6695
ML	3.00	3.85	-0.0024	0.1626	4.0057	1.1292	8.4912	1.6440	0.3756
ML	6.00	4. 6	0.0260	0.1533	3.3513	1.0328	7.1797	1.5117	0.4446
ML	9.00	4.80	0.0580	0.0796	3.5728	1.0664	7.3676	1.5314	0.4035
ML	12.00	5.45	0.0086	0.0841	5.1110	1.2755	9.9373	1.7785	0.1801
MN	0.00		-0.1592	0.2406	8.0850	1.6042	17.6802	2.3723	0.2301
MN	1.00	3.75	-0.1733	0.2893	5.4420	1.3161	9.5712	1.7455	0.5426
MN	3.00		-0.1615	0.2661	4.0157	1.1306	7.8094	1.5766	0.4565
MN	0.00	3.57	0.1959	0.1718	10.0455	1.7882	19.2461	2.4751	0.1182
MN	0.00		0.2100	0.2048	6.3312	1.4196	13.4941	2.0725	0.1915
MS	12.00	4.41	-0.0308	0.2061	3.6627	1.0798	6.4471	1.4325	0.1574
MS	6.00		0.0566	0.1964	2.8872	0.9587	5.5246	1.3261	0.3766
MSX	8.00		-0.0974	-0.0210	7.4784	1.5429	13.2584	2.0543	0.3892
MSX	7.00		0.0974	-0.0210	4.7556	1.2303	9.9681	1.7813	0.9479
PB	0.00	4.54	-0.1294	-0.0931	8.0948	1.6052	15.8624	2.2470	0.1959
PB	1.00	3.85	-0.1740	-0.0349	7.2496	1.5191	14.3310	2.1358	0.1655
PB	2.00	4.22	-0.1067	-0.0836	8.8504	1.6784	15.4649	2.2187	0.4811
PB	5.00		-0.1410	-0.0583	8.4977	1.6447	15.6514	2.2320	0.2130
PB	8.00	3.98	-0.1060	-0.0427	7.7598	1.5716	14.7657	2.1680	0.2268
PB	0.00	4.19	0.1329	-0.0019	5.2303	1.2903	11.2608	1.8933	0.3680
PB	3.00	4.69	0.2100	0.0109	5.4552	1.3177	10.7005	1.8456	0.1811
PB	5.00	4.38	0.2233	0.0261	6.4112	1.4285	11.6202	1.9232	0.2404
PB	7.00	3.78	0.1341	0.0691	6.2175	1.4068	11.4515	1.9092	0.3682
PB	9.00		0.1148	0.0788	6.1366	1.3976	11.3987	1.9048	0.3177
PB	12.00	4.88	0.1329	-0.0019	5.1866	1.2849	10.8011	1.8542	0.3860
PM	12.00		-0.0456	0.0224	5.1993	1.2865	11.1440	1.8834	1.2121
PM	18.00		-0.0456	0.0224	6.4002	1.4273	12.2524	1.9749	1.0698
PM	21.00		-0.0456	0.0224	8.3439	1.6297	15.0021	2.1853	0.9787
PM	0.00		0.0456	0.0224	8.6184	1.6563	18.4161	2.4212	0.4734
PM	0.00	3.12	0.0456	0.0224	9.3355	1.7238	20.4522	2.5515	0.4330
PR	0.00		-0.3851	-0.0915	5.3178	1.3010	11.6707	1.9274	0.2851
PR	0.00		-0.3851	-0.0915	5.6758	1.3441	12.6845	2.0094	0.0950
PRX	1.00	3.67	-0.4100	0.0223	2.1378	0.8249	3.6145	1.0726	0.6601
PRX	2.00	3.38	-0.3419	-0.0001	3.0833	0.9907	6.3106	1.4173	0.4687
PR	0.00		0.3789	-0.0468	7.1162	1.5050	15.3863	2.2131	0.8318
PRX	1.00	3.33	0.2165	0.1873	4.4204	1.1862	10.4669	1.8253	0.4321
PRX	3.00	3.30	0.2461	0.2901	5.4167	1.3131	10.5922	1.8362	0.6559
PRX	6.00	3.78	0.2171	0.0770	5.8289	1.3621	10.2172	1.8034	0.9131
PRX	7.00	3.70	0.3629	0.3671	7.0956	1.5029	11.5501	1.9174	0.7698
PRX	9.00	3.30	0.2753	0.2432	4.5597	1.2047	8.2987	1.6253	0.7696
RL	0.00	3.57	-0.4023	0.0212	12.5508	1.9988	24.3103	2.7818	0.4352
RL	3.00		-0.2906	0.0574	11.1455	1.8835	18.1149	2.4013	0.1932
RL	0.00	2.96	0.1354	0.0833	11.1288	1.8821	23.5867	2.7401	0.1749
RL	3.00		0.1425	0.0787	7.4813	1.5432	14.1236	2.1203	0.4119
SC	0.00	4.19	-0.1871	-0.0777	6.9819	1.4908	14.7573	2.1674	0.1095
SC	6.00		0.1404	0.1072	4.0704	1.1383	8.4247	1.6376	0.0559
SJ	0.00	3.54	-0.1443	0.1785	6.7112	1.4616	15.5863	2.2274	0.1956
SJ	0.00	4.17	-0.1265	0.0846	5.5645	1.3309	15.2510	2.2033	0.4278
SJ	0.00		-0.1530	0.1203	7.9161	1.5874	16.6737	2.3038	0.1717
SJ	1.00	3.43	-0.0059	-0.0497	8.9655	1.6893	19.4975	2.4912	1.2546
SJ	2.00	3.67	0.0186	0.0412	11.6364	1.9246	22.9265	2.7014	0.6682
SJ	3.00	3.93	0.1068	-0.0561	18.2088	2.4075	29.9592	3.0881	
SJ	5.00	3.75	0.0026	-0.0516	16.4926	2.2912	36.5902	3.4128	
SJ	9.00	3.46	0.0105	-0.0236	5.6933	1.3462	21.2317	2.5997	0.4654
SJ	1x		-0.0072	-0.0233	5.4935	1.3224	12.3623	1.9837	0.4716
SL	0.00	5.96	-0.4600	0.0602	7.5480	1.5500	15.7886	2.2418	0.5793
SL	0.00	5.93	-0.4600	0.0602	7.1926	1.5131	15.5430	2.2243	0.5081
SL	0.00		-0.4600	0.0602	8.0247	1.5982	16.4994	2.2917	0.4678
SL	3.00	5.95	-0.4600	0.0602	4.4018	1.1837	8.5220	1.6470	0.5630
SL	6.00	5.95	-0.4600	0.0602	4.0494	1.1353	8.0623	1.6020	0.7465
SL	0.00		0.4646	0.1941	6.9720	1.4897	14.4766	2.1466	0.4191
SL	0.00	4.89	0.4646	0.1941	6.8401	1.4756	14.3854	2.1399	0.3466
SL	1.00	4.85	0.4714	0.1402	6.7673	1.4677	10.6097	1.8377	0.4439

Subj	Visit	TMS pupil	pupilx	pupily	EOZ 1	EOZ 1 radius	EOZ 2	EOZ 2 radius	EOZ dc
SL	3.00	5.34	0.4714	0.1402	4.4792	1.1941	8.9395	1.6869	0.5368
SL	6.00	5.34	0.4714	0.1402	5.7086	1.3480	9.9995	1.7841	0.4212
SL	9.00	6.27	0.4539	0.1576	5.2114	1.2880	9.2931	1.7199	0.4748
SPX	0.00	3.46	0.0079	0.0550	7.1184	1.5053	15.5499	2.2248	0.1682
SPX	6.00	3.62	0.0730	0.0815	7.6736	1.5629	13.0647	2.0393	0.1408
SPX	9.00		0.0529	0.0873	6.7015	1.4605	12.1172	1.9639	0.1702
SPX	12.00	3.62	0.0529	0.0873	6.3105	1.4173	11.7075	1.9304	0.2368
SPX	0.00	4.27	-0.1870	-0.1752	9.9164	1.7767	19.2368	2.4745	0.2234
SPX	1.00	3.54	-0.0199	-0.0785	5.5998	1.3351	10.7941	1.8536	0.2388
SPX	3.00	3.41	-0.0571	-0.0070	6.4936	1.4377	12.0083	1.9551	0.1680
SPX	6.00	3.74	-0.0571	-0.0070	7.6378	1.5592	13.0364	2.0371	0.0993
SPY	0.00		-0.2440	0.0920	7.1449	1.5081	14.9280	2.1798	1.1415
SPY	1.00	4.46	-0.2166	0.0357	3.4963	1.0550	11.8309	1.9406	0.8399
SPY	3.00	4.64	-0.1229	0.0933	3.9069	1.1152	9.4959	1.7386	0.8777
SPY	6.00	3.85	-0.1142	0.1884	5.2596	1.2939	16.4810	2.2904	0.7452
SPY	12.00	4.41	0.0281	0.1408	11.8585	1.9429	21.0748	2.5900	0.4807
SPY	0.00		0.1903	0.0432	10.3479	1.8149	19.3080	2.4791	0.5079
SPY	0.00	3.96	0.2401	0.1709	7.4700	1.5420	16.9796	2.3248	0.5763
SPY	1.00	3.99	0.2111	0.2177	6.8929	1.4812	13.1513	2.0460	0.5684
SPY	7.00	4.1	0.2446	0.2709	6.5910	1.4484	13.1328	2.0446	0.5993
TZ	0.00	3.62	-0.0829	-0.0314	7.8410	1.5798	16.0256	2.2586	0.3121
TZ	1.00		-0.1033	-0.0135	5.4931	1.3223	11.0646	1.8767	0.3768
TZ	3.00		-0.0941	-0.0047	7.4109	1.5359	14.0313	2.1134	0.6461
TZ	0.00	3.54	0.0710	-0.0122	9.4803	1.7371	18.7802	2.4450	0.3136
TZ	1.00		0.1056	-0.0451	7.4996	1.5451	15.5257	2.2231	0.1976
TZ	3.00		0.0482	-0.0553	8.1608	1.6117	13.2643	2.0548	0.0618
VP	0.00		-0.2367	0.0373	9.1582	1.7074	18.9466	2.4558	0.3713
VP	1.00								
VP	3.00	3.70	-0.0974	0.2079	6.2520	1.4107	12.1390	1.9657	0.4567
VP	6.00	3.91	0.1390	-0.1425	6.8071	1.4720	12.8013	2.0186	0.6461
VP	9.00	3.28	0.0949	0.1575	6.9805	1.4906	13.1647	2.0471	0.3730
VP	0.00		0.1571	0.0042	8.9919	1.6918	19.2097	2.4728	0.3953
VP	0.00	4.6	-0.0555	0.2112	7.8349	1.5792	17.5468	2.3633	0.0835
VP	3.00	3.54	-0.1516	0.0809	9.1124	1.7031	15.3051	2.2072	0.2411
VP	6.00	3.38	-0.2475	0.3253	7.7293	1.5685	13.5963	2.0803	0.2017
WE	0.00		-0.1501	-0.0349	4.8952	1.2483	10.9891	1.8703	0.1760
WE	3.00	3.56	-0.3920	0.2883	5.9783	1.3795	12.1795	1.9690	0.3391
WE	6.00		-0.4082	0.1633	4.5232	1.1999	10.2515	1.8064	0.6438
WE	8.00	3.49	-0.3962	0.3027	6.4226	1.4298	12.2771	1.9768	0.7137
WE	12.00		-0.3895	0.1614	5.8926	1.3696	12.0400	1.9577	0.7622
WE	0.00		0.3273	0.1275	6.4556	1.4335	15.1276	2.1944	0.4463
WE	0.00	4.14	0.3273	0.1275	8.3921	1.6344	15.3461	2.2102	0.1245
WE	1.50	3.9	0.2454	0.2120	3.4633	1.0500	7.5196	1.5471	0.2500
WE	4.00	3.57	0.3071	0.1451	7.3427	1.5288	12.7290	2.0129	0.3252
WE	8.00	3.51	0.3287	0.2021	5.3682	1.3072	10.3328	1.8136	0.2997
YA	0.00		0.0000	0.0000	7.4062	1.5354	8.5866	1.6532	0.0927
YA	8.00		0.0000	0.0000	5.8978	1.3702	11.0391	1.8745	0.9394
YA	9.00		0.0000	0.0000	10.2928	1.8101	15.6636	2.2329	1.0466
YA	12.00		0.0000	0.0000	6.8441	1.4760	11.8039	1.9384	1.0814
YA	0.00		0.0000	0.0000	5.8022	1.3590	12.9065	2.0269	0.2524
YA	0.00		0.0000	0.0000	3.4027	1.0407	7.3972	1.5345	0.4964
YA	4.00		0.0000	0.0000	6.3861	1.4257	12.0736	1.9604	0.6140
YA	5.00		0.0000	0.0000	4.7147	1.2250	10.7661	1.8512	0.4995
YA	9.00		0.0000	0.0000	4.5466	1.2030	10.0779	1.7911	0.5030

Subj	Visit	PSF_Height	PSF_Vol 2min	PSF_Vol 5min	PSF_Rad 50%	PSF_Rad 90%	MTF_Area 15	MTF at 18.75	MTF at 30
AB	0.00	0.1808	0.5612	0.7653	0.0078	0.0442	18.2500	0.2146	0.0894
AB	0.00	0.1659	0.3870	0.6349	0.0163	0.0510	14.3826	0.1858	0.1058
AB	0.00	0.2852	0.5652	0.8590	0.0072	0.0304	19.2560	0.3040	0.1943
AB	3.00	0.3298	0.6799	0.9471	0.0050	0.0200	22.3926	0.3677	0.2230
AB	0.00	0.2812	0.5523	0.8075	0.0079	0.0426	18.7203	0.2820	0.1859
AB	1.00	0.0463	0.2532	0.6682	0.0196	0.0332	13.5522	0.0622	0.0365
AB	3.00	0.0672	0.1251	0.2302	0.0784	0.1203	8.8870	0.0777	0.0472
AB	6.00	0.1025	0.2736	0.6111	0.0182	0.0498	12.4363	0.0895	0.0743
AB	9.00	0.0526	0.1642	0.4471	0.0273	0.0480	11.8102	0.0600	0.0359
AC	0.00	0.1883	0.4202	0.7294	0.0132	0.0349	15.4155	0.2010	0.1261
AC	0.25	0.0953	0.1991	0.3876	0.0359	0.0910	10.9819	0.1016	0.0649
AC	1.00	0.0730	0.1840	0.3817	0.0345	0.0966	10.3024	0.0817	0.0482
AC	0.00	0.2079	0.4418	0.8319	0.0119	0.0285	18.6146	0.2188	0.1269
AC	1.00	0.1120	0.2715	0.4701	0.0278	0.1317	11.9247	0.1192	0.0614
AG	0.00	0.2928	0.5445	0.8554	0.0082	0.0305	18.6643	0.2972	0.1970
AG	2.00	0.1147	0.2888	0.4660	0.0279	0.0958	11.6041	0.1343	0.0690
AG	0.00	0.3408	0.5976	0.8356	0.0064	0.0329	19.8802	0.3383	0.2287
AG	1.00	0.1208	0.3658	0.6891	0.0151	0.0431	13.9437	0.1212	0.0732
AG	3.00	0.1386	0.3080	0.6559	0.0192	0.0444	12.8392	0.1494	0.0955
AG	6.00	0.2341	0.5091	0.8751	0.0096	0.0272	19.4557	0.2616	0.1522
AJ	15.00	0.1687	0.3551	0.7518	0.0139	0.0443	16.0071	0.1606	0.1065
AJ	18.00	0.1448	0.3295	0.8185	0.0155	0.0285	16.8602	0.1539	0.0841
AJ	0.00	0.2081	0.5449	0.8555	0.0090	0.0316	18.9862	0.2208	0.1088
AJ	9.00	0.0361	0.0946	0.2402	0.0538	0.1102	7.7784	0.0419	0.0253
AJ	12.00	0.0549	0.1179	0.2802	0.0424	0.0997	8.7542	0.0601	0.0413
AK	0.00	0.0997	0.2853	0.6435	0.0181	0.0587	13.7603	0.0970	0.0648
AK	0.00	0.1092	0.4232	0.7606	0.0115	0.0526	15.2293	0.0835	0.0584
AK	1.00	0.1280	0.2500	0.4503	0.0317	0.0843	11.9164	0.1350	0.0811
AK	3.00	0.1826	0.3833	0.6792	0.0147	0.0834	14.0640	0.1761	0.1099
AK	0.00	0.2795	0.5551	0.8410	0.0075	0.0334	19.0193	0.2962	0.1847
AK	1.00	0.0521	0.1166	0.2875	0.0406	0.0787	9.2398	0.0628	0.0390
AK	3.00	0.0700	0.2151	0.5706	0.0225	0.0528	12.8117	0.0802	0.0454
AM	0.00								
AM	2.00	0.1993	0.5725	0.9400	0.0082	0.0208	19.0489	0.2282	0.1163
AM	5.00	0.2383	0.5105	0.8643	0.0096	0.0269	18.7009	0.2561	0.1391
AM	8.00	0.3212	0.8020	0.9773	0.0045	0.0156	24.5413	0.4009	0.1908
AM	0.00								
AM	1.00	0.1523	0.2902	0.4132	0.0395	0.1265	11.8152	0.1592	0.1011
AM	3.00	0.1125	0.2789	0.6334	0.0183	0.0523	13.9658	0.1102	0.0761
AM	6.00	0.1909	0.4012	0.8391	0.0126	0.0331	16.8740	0.1910	0.1074
AM	9.00	0.1803	0.3898	0.7662	0.0138	0.0387	16.6769	0.1994	0.1094
BS	0.00	0.3783	0.6458	0.8830	0.0056	0.0269	21.5207	0.3706	0.2531
BS	6.00	0.0304	0.0823	0.2335	0.0547	0.1098	7.4924	0.0436	0.0324
BS	12.00	0.0539	0.1308	0.3212	0.0360	0.0685	9.9424	0.0656	0.0361
BS	16.00	0.0381	0.0930	0.2566	0.0434	0.0758	9.0413	0.0480	0.0387
BS	0.00	0.1119	0.2762	0.5324	0.0234	0.0378	15.2389	0.1319	0.0849
BS	0.00	0.1747	0.4466	0.9212	0.0110	0.0228	20.4097	0.1522	0.1165
BS	1.00	0.2528	0.5835	0.7914	0.0084	0.0457	19.3201	0.2468	0.1511
BY	0.00	0.1790	0.4330	0.8814	0.0112	0.0263	18.0073	0.1670	0.1269
BY	9.00	0.0489	0.1204	0.2776	0.0601	0.1300	8.3561	0.0537	0.0431
BY	12.00	0.0578	0.1437	0.3461	0.0368	0.0671	10.0573	0.0644	0.0409
BY	18.00	0.0860	0.2084	0.5069	0.0246	0.0518	12.1335	0.0970	0.0597
BY	0.00	0.2927	0.5646	0.8774	0.0078	0.0272	19.0744	0.2825	0.2009
BY	2.00	0.0881	0.3591	0.7747	0.0132	0.0366	15.1806	0.1033	0.0557
BY	3.00	0.1188	0.2848	0.5601	0.0215	0.0692	11.6069	0.1271	0.0854
CA	0.00	0.1060	0.3442	0.9756	0.0133	0.0212	19.4103	0.1340	0.0683
CA	3.00	0.1034	0.2209	0.4119	0.0340	0.0805	11.0355	0.1035	0.0618
CA	6.00	0.0680	0.2027	0.5490	0.0233	0.0619	13.1377	0.0755	0.0518
CA	0.00	0.1322	0.5267	0.9806	0.0096	0.0169	21.5224	0.1744	0.0930
CA	0.00	0.1163	0.2947	0.8492	0.0150	0.0282	16.8110	0.1296	0.0781
CA	3.00	0.2356	0.5450	0.8296	0.0082	0.0330	18.5297	0.2662	0.1489
CC	3.00	0.0327	0.0701	0.1525	0.0877	0.1660	5.8393	0.0423	0.0295
CC	6.00	0.0415	0.1004	0.2812	0.0545	0.1834	6.9436	0.0531	0.0346
CC	9.00	0.0344	0.0827	0.2245	0.0476	0.0835	8.3032	0.0393	0.0291
CC	0.00	0.1180	0.3793	0.8482	0.0127	0.0308	15.0480	0.1099	0.0700

Subj	Visit	PSF_ Height	PSF_Vol 2min	PSF_Vol 5min	PSF_Rad 50%	PSF_Rad 90%	MTF_Area 15	MTF at 18.75	MTF at 30
CC	4.00	0.0280	0.0619	0.1553	0.0743	0.1494	6.0407	0.0410	0.0327
CC	7.00	0.0316	0.0735	0.1934	0.0493	0.1016	7.0185	0.0434	0.0298
CC	10.00	0.0118	0.0268	0.0679	0.1417	0.2994	3.8556	0.0268	0.0247
CC	10.00	0.0210	0.0610	0.1369	0.0794	0.1580	6.1595	0.0364	0.0280
CE	0.00	0.3155	0.6086	0.8881	0.0063	0.0264	20.3104	0.3268	0.2120
CE	1.00	0.0420	0.0906	0.1819	0.0598	0.1596	6.7394	0.0563	0.0332
CE	4.00	0.0968	0.3392	0.6258	0.0179	0.0392	13.2261	0.0890	0.0549
CE	7.00	0.0964	0.2841	0.7766	0.0168	0.0495	15.6351	0.1185	0.0693
CE	0.00	0.3924	0.6528	0.8707	0.0053	0.0311	22.3003	0.3542	0.2739
CE	1.00								
CE	3.00	0.1065	0.2452	0.6565	0.0185	0.0612	13.3336	0.0960	0.0703
CE	6.00	0.1376	0.2855	0.5274	0.0232	0.0586	13.9854	0.1486	0.0854
CE	9.00	0.2592	0.4438	0.7555	0.0125	0.0599	17.6087	0.2715	0.1724
CH	0.00	0.0626	0.1984	0.5548	0.0232	0.0648	10.7245	0.0577	0.0479
CH	7.00	0.1774	0.5918	0.8073	0.0074	0.0360	18.9333	0.2133	0.0682
CH	9.00	0.2763	0.5287	0.8621	0.0089	0.0283	19.8472	0.2881	0.1963
CH	0.00	0.2649	0.6879	0.9515	0.0064	0.0203	21.7536	0.2904	0.1343
CH	3.00	0.0307	0.0867	0.1873	0.1123	0.2299	5.3745	0.0383	0.0312
CH	6.00	0.1694	0.4587	0.9076	0.0107	0.0242	20.6381	0.1853	0.1139
CM	0.00	0.2944	0.6590	0.8658	0.0053	0.0291	21.1814	0.3396	0.2174
CM	0.25	0.0657	0.1431	0.3110	0.0569	0.1769	8.8574	0.0740	0.0482
CM	1.00	0.1214	0.2774	0.5928	0.0209	0.0460	13.9632	0.1271	0.0786
CM	3.00	0.1914	0.5056	0.8331	0.0098	0.0298	17.1807	0.2010	0.1146
CM	0.00	0.2335	0.4520	0.7043	0.0120	0.0418	16.3195	0.2328	0.1532
CM	0.00								
CM	1.00	0.1809	0.3653	0.6356	0.0159	0.0547	14.7894	0.1809	0.1167
CR	0.00	0.3918	0.7455	0.9389	0.0039	0.0202	23.6258	0.4201	0.2735
CR	0.00	0.4603	0.7932	0.9801	0.0038	0.0162	24.9612	0.4695	0.3086
CR	0.00	0.1667	0.3887	0.9131	0.0126	0.0237	17.8857	0.1882	0.0892
CR	3.00	0.0712	0.1766	0.5650	0.0230	0.0423	13.2390	0.0933	0.0546
CT	2.00	0.1194	0.2851	0.4535	0.0306	0.1082	11.3208	0.1366	0.0722
CT	3.00	0.0893	0.2500	0.4329	0.0323	0.0608	10.6866	0.0956	0.0508
CT	0.00	0.1771	0.4860	0.8437	0.0104	0.0295	17.1312		
CT	0.00	0.2136	0.5303	0.9003	0.0094	0.0250	19.1163	0.2127	0.1283
CVP	0.00	0.2531	0.5563	0.8002	0.0074	0.0349	19.1774	0.2783	0.1516
CVP	1.00	0.1094	0.2639	0.5643	0.0198	0.0643	12.2608	0.0951	0.0727
CVP	3.00	0.1819	0.4434	0.8255	0.0113	0.0319	17.2255	0.1750	0.1246
CVP	4.00	0.0728	0.1965	0.6066	0.0222	0.0335	14.7416	0.0733	0.0511
CVP	6.00	0.0957	0.2691	0.6569	0.0199	0.0321	15.6425	0.1141	0.0711
CVP	9.00	0.0693	0.1700	0.4507	0.0273	0.0448	12.4159	0.0800	0.0469
CVP	0.00	0.4184	0.7608	0.9616	0.0036	0.0171	24.6773	0.4316	0.2807
CVP	0.00	0.2440	0.5363	0.9203	0.0091	0.0230	20.1261	0.2221	0.1566
CVP	1.00	0.4400	0.7197	0.9202	0.0037	0.0224	23.2499	0.4484	0.3152
CVP	3.00	0.2187	0.4635	0.8138	0.0108	0.0318	19.5276	0.2209	0.1353
CVP	6.00	0.0639	0.1352	0.2615	0.0502	0.0804	9.3201	0.0725	0.0452
DG	10.00	0.2841	0.5509	0.8463	0.0077	0.0309	19.2627	0.3126	0.1843
DG	10.00	0.1789	0.3190	0.5689	0.0210	0.0442	15.0246	0.1858	0.1197
DH	0.00	0.2628	0.5753	0.9002	0.0072	0.0250	19.4530	0.2921	0.1815
DH	1.00	0.2011	0.4318	0.6767	0.0129	0.0536	16.4504	0.2105	0.1230
DH	0.00	0.3765	0.7632	0.9807	0.0040	0.0164	23.8761	0.4039	0.2518
DH	1.00	0.1046	0.2512	0.4931	0.0254	0.0595	13.1496	0.1138	0.0713
DKX	0.00	0.1624	0.3893	0.8784	0.0127	0.0265	18.1027	0.1730	0.1022
DKX	6.00	0.0841	0.1952	0.6315	0.0214	0.0357	14.2157	0.0975	0.0665
DKX	9.00	0.0757	0.2159	0.5209	0.0241	0.0637	12.2243	0.1108	0.0656
DKX	11.00	0.1216	0.3271	0.8221	0.0156	0.0336	14.0541	0.1587	0.0660
DKX	12.00	0.1669	0.6839	0.9151	0.0068	0.0218	20.7160	0.1733	0.0800
DKX	18.00	0.0509	0.1296	0.4311	0.0294	0.0556	10.6866	0.0618	0.0353
DKX	0.00	0.2183	0.4553	0.9030	0.0112	0.0249	18.8252	0.2313	0.1360
DKX	1.00	0.0105	0.0365	0.0918	0.1071	0.1942	4.1212	0.0293	0.0249
DKX	3.00	0.1858	0.4578	0.7630	0.0116	0.0410	15.9903	0.2022	0.1205
DKX	4.00	0.0843	0.3188	0.7550	0.0171	0.0383	14.3433	0.1006	0.0431
DKX	11.00	0.1131	0.2706	0.4998	0.0250	0.0592	11.3358	0.1114	0.0662
DKY	0.00	0.1104	0.2651	0.6626	0.0199	0.0340	15.4719	0.1229	0.0757
DKY	6.00	0.0717	0.1859	0.6743	0.0205	0.0440	14.1931	0.1101	0.0490
DKY	9.00	0.0757	0.1987	0.6481	0.0210	0.0425	12.8119	0.1134	0.0584

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Subj	Visit	PSF_ Height	PSF_Vol 2min	PSF_Vol 5min	PSF_Rad 50%	PSF_Rad 90%	MTF_Area 15	MTF at 18.75	MTF at 30
DKY	12.00	0.0787	0.2280	0.6246	0.0199	0.0566	12.3973	0.1082	0.0462
DS	0.00	0.3237	0.5618	0.7544	0.0075	0.0481	19.8631	0.3220	0.2077
DS	0.25	0.0169	0.0434	0.1096	0.0827	0.1739	4.0873	0.0323	0.0287
DS	0.00	0.2341	0.5679	0.9748	0.0086	0.0194	21.0515	0.2176	0.1617
EO	0.00	0.2862	0.6108	0.9068	0.0064	0.0245	20.2793	0.3143	0.2065
EO	3.00	0.3284	0.6432	0.8384	0.0054	0.0357	21.0049	0.3409	0.2102
EO	6.00	0.1095	0.2883	0.7991	0.0154	0.0415	15.8429	0.1179	0.0748
EO	9.00	0.0838	0.2139	0.4545	0.0278	0.0476	11.3800	0.1062	0.0483
EO	0.00	0.3303	0.6065	0.9000	0.0064	0.0250	20.2130	0.3296	0.2162
EO	6.00	0.1614	0.3564	0.5620	0.0198	0.0826	14.1544	0.1842	0.1005
EO	9.00	0.3457	0.6104	0.8363	0.0065	0.0383	20.9891	0.3186	0.2285
EO	12.00	0.2270	0.4627	0.8633	0.0109	0.0303	18.2135	0.2111	0.1450
GA	0.00	0.4341	0.7917	1.0000	0.0032	0.0143	25.0613	0.4607	0.2988
GA	0.00	0.3877	0.7954	0.9858	0.0039	0.0151	25.1045	0.4390	0.2625
GA	1.00	0.1807	0.3558	0.6921	0.0163	0.0381	16.2307	0.1894	0.1104
GA	3.00	0.2728	0.5570	0.7969	0.0077	0.0368	19.0224	0.3032	0.1799
GA	4.00	0.2230	0.3777	0.5888	0.0185	0.0621	13.9432	0.2113	0.1534
GA	6.00	0.2732	0.4783	0.7206	0.0110	0.0459	16.8875	0.2698	0.1858
GA	9.00	0.2892	0.5221	0.7693	0.0090	0.0460	17.9360	0.2928	0.1910
GA	12.00	0.1222	0.3803	0.7726	0.0128	0.0431	15.6163	0.1238	0.0828
GA	0.00	0.3534	0.6679	0.9093	0.0048	0.0242	22.0158	0.3888	0.2368
GA	0.00	0.1854	0.3541	0.8862	0.0148	0.0260	18.3491	0.2259	0.1275
GA	0.00	0.3713	0.7031	0.9370	0.0043	0.0209	22.8236	0.3861	0.2679
GA	1.00	0.1164	0.3216	0.9270	0.0141	0.0236	18.4582	0.1516	0.0846
GA	3.00	0.2619	0.5338	0.8315	0.0088	0.0321	18.4079	0.2489	0.1801
GA	6.00	0.1577	0.4000	0.8794	0.0119	0.0277	17.8768	0.1494	0.1019
GA	9.00	0.1966	0.4785	0.9301	0.0103	0.0234	20.1115	0.1843	0.1361
GU	0.00	0.3451	0.6340	0.9172	0.0055	0.0234	21.1312	0.3561	0.2316
GU	0.00	0.2485	0.4799	0.8004	0.0107	0.0330	16.9680	0.2494	0.1686
GU	1.00	0.0743	0.2280	0.3564	0.0466	0.1651	8.8603	0.0904	0.0430
GU	3.00	0.1112	0.2406	0.4636	0.0294	0.0968	11.8913	0.1151	0.0694
GU	6.00	0.0593	0.2944	0.8857	0.0139	0.0269	12.7414	0.0890	0.0442
GU	0.00	0.2084	0.6147	0.9334	0.0069	0.0228	20.0695	0.2462	0.1082
GU	3.00	0.0951	0.2079	0.4265	0.0305	0.0530	11.1820	0.1072	0.0614
GU	6.00	0.1392	0.3046	0.4743	0.0276	0.0830	11.5921	0.1677	0.0993
GU	9.00	0.0969	0.2501	0.6168	0.0176	0.0702	13.5472	0.0907	0.0603
JF	0.00	0.1227	0.3743	0.9899	0.0129	0.0219	19.2598	0.1630	0.0813
JF	3.00	0.0579	0.1308	0.2782	0.0543	0.1159	8.4335	0.0616	0.0367
JF	6.00	0.1021	0.2155	0.3902	0.0416	0.1078	10.6412	0.1024	0.0621
JF	0.00	0.4086	0.7372	0.9783	0.0043	0.0171	23.3759	0.3955	0.2722
JF	3.00	0.2009	0.3497	0.5239	0.0226	0.1076	13.1449	0.1961	0.1313
JF	6.00	0.0797	0.1826	0.5616	0.0235	0.0811	11.1208	0.0976	0.0543
JF	9.00	0.1510	0.3306	0.5940	0.0197	0.0517	12.8896	0.1497	0.1008
JG	6.00	0.0854	0.2822	0.5872	0.0208	0.0632	11.4094	0.0843	0.0546
JG	7.00	0.0926	0.1847	0.3778	0.0339	0.0679	9.5150	0.0987	0.0555
JG	9.00	0.1440	0.3917	0.7914	0.0125	0.0346	15.6556	0.1306	0.0877
JG	0.00	0.2002	0.4737	0.9436	0.0108	0.0233	20.5578	0.2312	0.1293
JG	1.00	0.0873	0.2774	0.5548	0.0206	0.0762	11.6931	0.0979	0.0483
JG	3.00	0.1021	0.2089	0.3768	0.0353	0.0970	9.1038	0.1066	0.0621
JH	0.00	0.2188	0.4655	0.8651	0.0110	0.0266	18.6251	0.2233	0.1381
JH	1.00	0.0725	0.2102	0.5213	0.0239	0.0464	11.2940	0.0900	0.0585
JH	2.00	0.2506	0.6281	0.8383	0.0067	0.0429	20.6120	0.2977	0.1313
JH	3.00	0.2210	0.5799	0.8320	0.0069	0.0424	19.0081	0.2697	0.1286
JH	6.00	0.1028	0.2254	0.5238	0.0241	0.0608	12.2969	0.1024	0.0681
JH	9.00	0.0810	0.1745	0.3386	0.0400	0.0715	10.6250	0.0907	0.0523
JH	12.00	0.1670	0.3091	0.6174	0.0187	0.0500	15.0037	0.1663	0.1010
JH	0.00	0.1234	0.4926	0.9984	0.0101	0.0174	21.4487	0.1402	0.0878
JH	3.00	0.0917	0.1835	0.3712	0.0379	0.0835	10.2368	0.0918	0.0590
JH	6.00	0.0452	0.1009	0.2272	0.0544	0.0976	7.6945	0.0496	0.0403
JH	9.00	0.0589	0.1468	0.3845	0.0341	0.0752	10.3541	0.0773	0.0439
JH	12.00	0.0659	0.1490	0.3343	0.0410	0.0812	9.7324	0.0715	0.0465
JH	17.00	0.1545	0.3011	0.4706	0.0282	0.0963	11.4867	0.1615	0.1066
JN	0.00	0.2400	0.4400	0.7137	0.0126	0.0480	15.8654	0.2399	0.1603
JN	0.00	0.2775	0.5251	0.8601	0.0090	0.0278	18.3988	0.2807	0.1827
JN	1.00	0.2284	0.5448	0.8118	0.0087	0.0375	18.7963	0.2350	0.1405

Subj	Visit	PSF_Height	PSF_Vol 2min	PSF_Vol 5min	PSF_Rad 50%	PSF_Rad 90%	MTF_Area 15	MTF at 18.75	MTF at 30
JN	2.00	0.1679	0.4327	0.8868	0.0118	0.0257	18.2247	0.1710	0.0962
JN	5.00	0.2679	0.4817	0.7157	0.0109	0.0491	17.1530	0.2652	0.1712
JN	8.00	0.1246	0.3011	0.7577	0.0151	0.0336	16.2126	0.1170	0.0751
JN	0.00	0.3285	0.6226	0.9319	0.0062	0.0226	20.7264	0.3187	0.2190
JN	3.00	0.0898	0.1943	0.5349	0.0234	0.1188	11.8814	0.0812	0.0650
JN	5.00	0.1279	0.2790	0.5689	0.0211	0.0615	13.6405	0.1334	0.0771
JN	6.00	0.0885	0.1837	0.3554	0.0412	0.1045	10.1015	0.0933	0.0548
JN	9.00	0.1700	0.3647	0.5658	0.0194	0.1128	14.1771	0.1828	0.1008
JN	12.00	0.1885	0.3738	0.6370	0.0158	0.0983	13.8061	0.1847	0.1202
JPX	6.00	0.0879	0.2234	0.5108	0.0245	0.0449	13.7273	0.0968	0.0558
JPX	12	0.1075	0.2681	0.7630	0.0171	0.0432	14.4186	0.1368	0.0669
JPX	0	0.2594	0.5454	0.8857	0.0087	0.0262	20.2433	0.2552	0.1652
JPX	0	0.3291	0.5882	0.9020	0.0070	0.0249	21.3628	0.3391	0.2139
JR	6	0.1315	0.4085	0.7292	0.0121	0.0434	15.4044	0.1254	0.0827
JR	12.00	0.2406	0.4376	0.7167	0.0126	0.0433	15.8581	0.2359	0.1597
JR	0.00	0.1813	0.3555	0.5875	0.0193	0.0552	13.4128	0.1831	0.1219
JR	4.00	0.0729	0.1722	0.6644	0.0207	0.0328	15.2325	0.1027	0.0650
JRX	12.00	0.0967	0.2370	0.6394	0.0185	0.0839	13.2112	0.0842	0.0686
JRX	9.00	0.1203	0.2651	0.5566	0.0219	0.0430	13.6500	0.1307	0.0820
JW	0.00	0.2983	0.5435	0.7693	0.0082	0.0419	18.8053	0.2940	0.1953
JW	9.00	0.0206	0.0473	0.1160	0.1064	0.2183	5.1863	0.0325	0.0329
JWX	0.00	0.2925	0.5210	0.7538	0.0092	0.0431	18.0029	0.2828	0.1909
JWX	0.00	0.2466	0.5127	0.8650	0.0094	0.0281	18.6730	0.2736	0.1749
JWX		0.0314	0.1399	0.3706	0.0365	0.0962	7.6491	0.0339	0.0237
KA	0.00	0.1611	0.3966	0.9309	0.0123	0.0227	17.5886	0.1693	0.0912
KA	0.00	0.1434	0.3508	0.8237	0.0144	0.0322	15.8948	0.1618	0.0776
KA	0.00	0.2695	0.5820	0.8785	0.0068	0.0266	19.5959	0.3103	0.1944
KC	0.00	0.3278	0.6749	0.9678	0.0055	0.0189	23.0693	0.3556	0.2140
KC	0.00	0.3138	0.8509	1.0000	0.0046	0.0114	24.9578	0.3175	0.1918
KC	3.00	0.0693	0.1743	0.4845	0.0259	0.0450	12.3216	0.0667	0.0516
LC	0.00	0.4402	0.7950	0.9882	0.0035	0.0136	24.9005	0.4273	0.2965
LC	0.00	0.3416	0.6577	0.9502	0.0050	0.0196	21.5964	0.3636	0.2530
LC	3.00	0.0609	0.1376	0.2799	0.0506	0.1041	8.9695	0.0656	0.0415
LC	6.00	0.0591	0.1590	0.3150	0.0467	0.0845	10.0355	0.0696	0.0390
LC	0.00	0.3340	0.6022	0.8271	0.0062	0.0347	20.4099	0.3420	0.2166
LC	6.00	0.0438	0.1028	0.2367	0.0588	0.0916	9.0630	0.0587	0.0347
LC	9.00	0.0501	0.1189	0.2754	0.0464	0.0917	8.9136	0.0597	0.0372
LM	0.00	0.1807	0.4016	0.6881	0.0142	0.0368	18.2657	0.2260	0.1122
LM	3.00	0.1575	0.3230	0.5989	0.0188	0.0523	14.9966	0.1626	0.1047
LM	6.00	0.1523	0.3049	0.5526	0.0212	0.0546	13.8741	0.1520	0.0978
LM	9.00	0.1488	0.3016	0.4768	0.0278	0.0996	11.7302	0.1455	0.0981
LM	12.00	0.1183	0.3484	0.5831	0.0184	0.0634	13.1430	0.1171	0.0668
LM	16.00	0.1550	0.2866	0.4292	0.0338	0.0857	12.3345	0.1634	0.1012
LM	20.00	0.2237	0.3824	0.5594	0.0195	0.0554	15.4174	0.2263	0.1443
LM	24.00	0.1765	0.4449	0.8733	0.0118	0.0264	17.5214	0.1935	0.1106
MBX	9.00	0.0332	0.0832	0.2303	0.0466	0.0729	8.8758	0.0470	0.0303
MBX	12.00	0.1563	0.2903	0.5894	0.0211	0.0524	13.7460	0.1564	0.1015
MBX	18.00	0.1569	0.2858	0.4370	0.0332	0.1272	10.9157	0.1587	0.1125
MBX	0.00	0.2707	0.4879	0.7820	0.0104	0.0393	17.2361	0.2583	0.1785
MBX	3.00	0.0300	0.0841	0.1738	0.0788	0.1802	5.1423	0.0407	0.0309
MBX	6.00	0.0186	0.0557	0.1400	0.0789	0.1927	5.0858	0.0367	0.0274
MBX	12.00	0.0230	0.0539	0.1334	0.1045	0.1646	6.1263	0.0359	0.0351
MBY	0.00	0.2505	0.4571	0.8236	0.0113	0.0335	19.1931	0.2472	0.1612
MBY	0.00	0.3257	0.5984	0.8412	0.0064	0.0316	20.1024	0.3330	0.2236
MBY	0.00	0.3123	0.5781	0.8094	0.0068	0.0355	19.6988	0.3223	0.2066
MBY	0.00	0.1221	0.2821	0.7296	0.0185	0.0319	14.7127	0.1351	0.0769
MBY	0.00	0.1566	0.3374	0.6911	0.0171	0.0333	15.2687	0.1597	0.1082
MBY	5.00	0.0370	0.0856	0.2070	0.0587	0.0934	7.6597	0.0494	0.0302
MBY	6.00	0.0447	0.1025	0.2419	0.0603	0.1053	8.2713	0.0559	0.0344
ML	0.00	0.1927	0.4138	0.7445	0.0136	0.0331	15.2536	0.1965	0.1268
ML	3.00	0.0876	0.2020	0.4770	0.0264	0.0471	12.4543	0.0997	0.0558
ML	6.00	0.0502	0.1105	0.2254	0.0693	0.1470	7.8430	0.0555	0.0346
ML	9.00	0.0414	0.1057	0.2695	0.0411	0.0690	8.9868	0.0499	0.0372
ML	12.00	0.0579	0.1490	0.4953	0.0252	0.0683	10.8856	0.0855	0.0461
ML	15.00	0.0775	0.3232	0.8240	0.0132	0.0371	12.9094	0.0597	0.0345

Subj	Visit	PSF_Height	PSF_Vol 2min	PSF_Vol 5min	PSF_Rad 50%	PSF_Rad 90%	MTF_Area 15	MTF at 18.75	MTF at 30
ML	0.00	0.3800	0.6736	0.9549	0.0052	0.0212	22.1299	0.3680	0.2472
ML	0.00	0.3704	0.6931	0.9342	0.0048	0.0206	22.4523	0.3852	0.2459
ML	1.00	0.0222	0.0539	0.1293	0.0811	0.1443	5.9106	0.0364	0.0274
ML	3.00	0.0513	0.1212	0.3033	0.0393	0.0710	9.6371	0.0657	0.0363
ML	6.00	0.1105	0.2262	0.3607	0.0442	0.1100	9.2022	0.1247	0.0846
ML	9.00	0.0422	0.1017	0.2725	0.0382	0.0756	9.2522	0.0577	0.0334
ML	12.00	0.0634	0.2488	0.8733	0.0173	0.0295	11.2619	0.1024	0.0465
MN	0.00	0.2004	0.5517	0.8143	0.0080	0.0327	18.5656	0.2431	0.1127
MN	1.00	0.0660	0.1664	0.3301	0.0456	0.1540	8.4478	0.0657	0.0482
MN	3.00	0.0336	0.1145	0.3386	0.0345	0.1312	7.9640	0.0476	0.0318
MN	0.00	0.2888	0.6424	0.9412	0.0072	0.0215	21.4070	0.2814	0.1721
MN	0.00	0.0924	0.3079	0.9417	0.0142	0.0220	17.9160	0.1349	0.0564
MS	12.00	0.0371	0.1417	0.2398	0.0745	0.1445	6.8831	0.0504	0.0315
MS	6.00	0.0542	0.2072	0.6842	0.0205	0.0336	11.3389	0.0675	0.0373
MSX	8.00	0.1145	0.2687	0.5624	0.0216	0.0510	14.2940	0.1056	0.0705
MSX	7.00	0.0480	0.1132	0.2663	0.0549	0.1182	8.3989	0.0525	0.0412
PB	0.00	0.3539	0.6100	0.8909	0.0062	0.0264	20.5317	0.3448	0.2363
PB	1.00	0.1085	0.2587	0.6747	0.0196	0.0346	13.2254	0.1219	0.0715
PB	2.00	0.1209	0.2478	0.5214	0.0240	0.0444	13.5460	0.1347	0.0774
PB	5.00	0.1601	0.3989	0.7831	0.0121	0.0380	16.7939	0.1435	0.1043
PB	8.00	0.2823	0.5306	0.7598	0.0084	0.0437	18.0621	0.3028	0.2015
PB	0.00	0.1331	0.3634	0.6053	0.0176	0.0890	13.6151	0.1426	0.0741
PB	3.00	0.0881	0.2113	0.5734	0.0226	0.0655	10.9111	0.1037	0.0584
PB	5.00	0.0665	0.1648	0.5065	0.0248	0.0491	13.3507	0.0864	0.0509
PB	7.00	0.1223	0.3308	0.6131	0.0165	0.0709	13.5610	0.1178	0.0752
PB	9.00	0.1905	0.3574	0.6110	0.0181	0.0775	13.5220	0.1689	0.1210
PB	12.00	0.1083	0.2933	0.4904	0.0258	0.0917	11.2604	0.1233	0.0606
PM	12.00	0.0518	0.1056	0.2214	0.0630	0.1133	7.8885	0.0544	0.0358
PM	18.00	0.0418	0.1043	0.2509	0.0514	0.1361	8.1763	0.0476	0.0385
PM	21.00	0.0969	0.2479	0.4671	0.0274	0.1581	10.4730	0.0891	0.0595
PM	0.00	0.1707	0.3961	0.7393	0.0143	0.0408	15.9095	0.1746	0.1046
PM	0.00	0.2414	0.4267	0.6632	0.0138	0.0530	17.2106	0.2505	0.1530
PR	0.00	0.1876	0.3613	0.5993	0.0184	0.0603	13.4410	0.1903	0.1362
PR	0.00	0.1891	0.3915	0.6322	0.0159	0.0539	14.4294	0.1965	0.1225
PRX	1.00	0.0084	0.0075	0.0330	0.1176	0.2241	3.4382	0.0291	0.0270
PRX	2.00	0.0337	0.0777	0.1745	0.0650	0.1305	6.3622	0.0426	0.0306
PR	0.00	0.1443	0.4874	0.6738	0.0105	0.0648	17.1664	0.1711	0.0873
PRX	1.00	0.0414	0.1369	0.4552	0.0278	0.0745	9.0044	0.0460	0.0372
PRX	3.00	0.0718	0.1898	0.4218	0.0304	0.0748	10.7390	0.0848	0.0465
PRX	6.00	0.0700	0.1645	0.4117	0.0326	0.0859	10.5305	0.0829	0.0428
PRX	7.00	0.1302	0.3135	0.5196	0.0233	0.1029	12.3619	0.1445	0.0747
PRX	9.00	0.0585	0.1550	0.2906	0.0431	0.1174	8.5182	0.0627	0.0450
RL	0.00	0.4891	0.8786	1.0000	0.0025	0.0108	27.1796	0.5052	0.3503
RL	3.00	0.1109	0.3088	0.7328	0.0158	0.0391	14.0025	0.1127	0.0622
RL	0.00	0.3445	0.7434	0.9908	0.0036	0.0167	23.6886	0.4056	0.2769
RL	3.00	0.0618	0.1634	0.5127	0.0245	0.0451	12.6828	0.0855	0.0464
SC	0.00	0.0966	0.2223	0.5574	0.0229	0.0360	13.7663	0.1062	0.0670
SC	6.00	0.0399	0.0934	0.2357	0.0521	0.0793	8.4052	0.0468	0.0390
SJ	0.00	0.0950	0.3566	0.8582	0.0126	0.0302	17.9357		
SJ	0.00	0.1478	0.3062	0.5976	0.0207	0.0349	15.7879	0.1489	0.0861
SJ	0.00	0.1192	0.2855	0.7314	0.0180	0.0326	15.3214	0.1497	0.0771
SJ	1.00	0.0284	0.1141	0.4353	0.0295	0.0616	8.2600	0.0422	0.0277
SJ	2.00	0.1140	0.2498	0.4011	0.0356	0.0801	10.7096	0.1169	0.0715
SJ	3.00	0.0537	0.1096	0.2519	0.0834	0.1663	7.0865	0.0591	0.0423
SJ	5.00	0.0454	0.1330	0.3178	0.0521	0.1787	8.5671	0.0558	0.0384
SJ	9.00	0.1922	0.4381	0.6172	0.0134	0.0764	15.2372	0.2097	0.1434
SJ	1x								
SL	0.00	0.1555	0.7590	0.8921	0.0065	0.0268	21.3849	0.1639	0.0469
SL	0.00	0.2804	0.5179	0.8013	0.0092	0.0418	17.8576	0.2830	0.1885
SL	0.00	0.3341	0.6088	0.8624	0.0062	0.0312	20.1988	0.3334	0.2201
SL	3.00	0.0490	0.1181	0.2408	0.0524	0.0913	7.5008	0.0574	0.0390
SL	6.00	0.0426	0.1074	0.3598	0.0320	0.0606	10.1126	0.0607	0.0355
SL	0.00	0.2515	0.4655	0.7372	0.0115	0.0467	16.3697	0.2498	0.1749
SL	0.00	0.2549	0.4717	0.7366	0.0112	0.0434	16.5758	0.2534	0.1761
SL	1.00	0.1350	0.3068	0.5104	0.0239	0.0692	13.3325	0.1416	0.0809

Subj	Visit	PSF_Height	PSF_Vol 2min	PSF_Vol 5min	PSF_Rad 50%	PSF_Rad 90%	MTF_Area 15	MTF at 18.75	MTF at 30
SL	3.00	0.0507	0.1274	0.3688	0.0318	0.0496	10.6089	0.0530	0.0354
SL	6.00	0.1005	0.4464	0.6339	0.0121	0.0747	14.5089	0.1059	0.0367
SL	9.00	0.0931	0.1987	0.4041	0.0341	0.1059	10.2385	0.1059	0.0601
SPX	0.00	0.2667	0.5085	0.7955	0.0096	0.0345	17.6870	0.2732	0.1816
SPX	6.00	0.2395	0.4667	0.6716	0.0119	0.0561	16.2672	0.2649	0.1761
SPX	9.00	0.0934	0.2467	0.6322	0.0193	0.0508	13.3742	0.1065	0.0543
SPX	12.00	0.1339	0.3155	0.6223	0.0165	0.0602	13.2275	0.1188	0.0872
SPX	0.00	0.3986	0.7152	0.9787	0.0040	0.0183	23.0955	0.4055	0.2837
SPX	1.00	0.0916	0.2322	0.5893	0.0219	0.0476	12.9001	0.1114	0.0606
SPX	3.00	0.1163	0.2419	0.5017	0.0249	0.0535	12.5216	0.1157	0.0756
SPX	6.00	0.1529	0.3277	0.7930	0.0150	0.0315	16.4550	0.1426	0.0996
SPY	0.00	0.1967	0.4457	0.6788	0.0112	0.0785	16.4779	0.1986	0.1229
SPY	1.00	0.0721	0.1770	0.5747	0.0233	0.0611	12.2483	0.0855	0.0598
SPY	3.00	0.0983	0.2403	0.4192	0.0336	0.0933	9.9510	0.1088	0.0619
SPY	6.00	0.1312	0.2883	0.5382	0.0228	0.0939	11.6268	0.1335	0.0858
SPY	12.00	0.1290	0.3490	0.8462	0.0137	0.0385	16.8861	0.1379	0.0783
SPY	0.00	0.4462	0.7672	0.9313	0.0034	0.0212	24.6357	0.4849	0.3094
SPY	0.00	0.2268	0.6181	0.9552	0.0074	0.0177	22.0423	0.2389	0.1584
SPY	1.00	0.1633	0.3802	0.7009	0.0139	0.0656	15.4370	0.1475	0.0963
SPY	7.00	0.2006	0.4456	0.6561	0.0131	0.0637	15.6897	0.2319	0.1349
TZ	0.00	0.2804	0.5166	0.7711	0.0094	0.0377	17.7027	0.2729	0.1887
TZ	1.00	0.0699	0.1589	0.3329	0.0408	0.0706	9.7105	0.0768	0.0479
TZ	3.00	0.0844	0.1915	0.4089	0.0315	0.0580	10.7557	0.0909	0.0530
TZ	0.00	0.2216	0.4811	0.8648	0.0103	0.0296	20.1948	0.2082	0.1493
TZ	1.00	0.1745	0.3981	0.6449	0.0155	0.0632	14.4526	0.1675	0.1000
TZ	3.00	0.1276	0.3169	0.6963	0.0171	0.0471	12.8234	0.1395	0.0802
VP	0.00	0.3252	0.6705	0.9517	0.0053	0.0200	21.5663	0.3537	0.2138
VP	1.00								
VP	3.00	0.0887	0.2074	0.4652	0.0272	0.0646	11.8648	0.0991	0.0564
VP	6.00	0.1908	0.3426	0.5689	0.0199	0.0738	12.9764	0.1804	0.1256
VP	9.00	0.0809	0.1974	0.6351	0.0195	0.0647	12.2931	0.0993	0.0562
VP	0.00	0.3195	0.6464	0.8756	0.0056	0.0273	21.1914	0.3391	0.2083
VP	0.00	0.2388	0.5145	0.8203	0.0095	0.0322	17.7917	0.2492	0.1511
VP	3.00	0.0931	0.2344	0.4900	0.0256	0.0499	11.9526	0.1123	0.0581
VP	6.00	0.1211	0.3977	0.7743	0.0129	0.0489	15.5431	0.1518	0.0746
WE	0.00	0.0727	0.1676	0.4433	0.0278	0.0483	12.8117	0.0924	0.0537
WE	3.00	0.0719	0.2110	0.5706	0.0228	0.0432	14.1211	0.0975	0.0520
WE	6.00	0.1215	0.2378	0.4079	0.0340	0.1151	9.8142	0.1222	0.0850
WE	8.00	0.0936	0.2177	0.4490	0.0277	0.0937	10.8701	0.0950	0.0596
WE	12.00	0.1187	0.2566	0.5761	0.0213	0.0952	11.8637	0.1279	0.0837
WE	0.00	0.1133	0.3762	0.7496	0.0121	0.0551	17.0728	0.1128	0.0902
WE	0.00	0.1005	0.4321	0.6957	0.0118	0.0404	14.9864	0.1130	0.0595
WE	1.50	0.0445	0.1179	0.3599	0.0382	0.0875	8.9756	0.0586	0.0369
WE	4.00	0.1417	0.5175	0.7007	0.0096	0.0801	16.8837	0.1902	0.0873
WE	8.00	0.0730	0.1721	0.3691	0.0351	0.0786	10.1722	0.0907	0.0475
YA	0.00	0.1346	0.4754	0.9933	0.0104	0.0169	21.6634	0.1408	0.0965
YA	8.00	0.0597	0.1357	0.2921	0.0623	0.1718	7.4909	0.0684	0.0487
YA	9.00	0.0599	0.2041	0.3446	0.0468	0.0927	9.9524	0.0723	0.0384
YA	12.00	0.0575	0.1436	0.2897	0.0523	0.1244	8.4694	0.0703	0.0449
YA	0.00	0.1994	0.3861	0.6446	0.0162	0.0471	14.4557	0.2015	0.1301
YA	0.00	0.1346	0.2386	0.3901	0.0376	0.1123	9.6855	0.1262	0.0936
YA	4.00	0.1085	0.2393	0.6206	0.0203	0.1380	12.5505	0.1179	0.0660
YA	5.00	0.0504	0.1196	0.2987	0.0382	0.0957	8.9515	0.0586	0.0325
YA	9.00	0.0571	0.1413	0.3353	0.0433	0.1543	9.1449	0.0663	0.0389

Appendix B
Klyce Corneal Statistics
Information extracted from the Help Menu on TMS-2™

The Corneal Statistics program was developed by Prof. Stephen D. Klyce, PhD, of Louisiana State University, exclusively for the TMS-2.

Corneal Statistics Screen
The screen consists of the following areas:

- A video image with the superimposed green, processed data rings
- An Absolute Scale map. Right click the mouse on the map to view the Options Window.
- The Patient History information including Exam Number, Exam Date, Patient Name, and Eye.
- A color coded Absolute Scale. Right click the mouse on the color scale to choose a different scale.

- The Corneal Statistics are color-coded in accordance with the Range scale. Move the mouse over different statistics and click to view the Definition Window. The Definition Window contains detailed explanations of each statistic. The value from the exam is color-coded according to the Range Scale.

- The Range scale is color-coded as green (normal), yellow (suspect), and orange (abnormal). The numerical cut-off values between normal/suspect and suspect/abnormal are displayed along the scale. Both the text in the Definition Window and the values in the Corneal Statistics box are color-coded according to this scale.

Statistics Defined:

SimK
Simulated Keratometry is obtained from the greatest power observed in the corneal surface from an average of rings 6-8 along every meridian. The power and axis orthogonal to the highest power are also reported as it is in traditional keratometry. Higher than normal values are often associated with keratoconus, penetrating keratoplasty, and the occasional steep normal. Lower than normal values occur with myopic refractive surgical corrections and the rare flat cornea.

MinK
Minimum Keratometry Value — Often the meridians of highest and lowest power are not orthogonal, and it is useful to know the meridian for which the actual minimum power occurs, particularly in the planning of astigmatic keratotomy. This situation most often occurs with keratoconus, penetrating keratoplasty, and trauma, although it may be present after cataract surgery as well.

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Cyl

The cylinder of the corneal surface is obtained from the SimK readings. Higher than normal values of Cyl are associated with several pathologies, trauma, and surgery.

ACP

Average Corneal Power. The ACP is an area-corrected average of the corneal power ahead of the entrance pupil. It is generally equal to the keratometric spherical equivalent except for decentered refractive surgical procedures. Abnormal values occur for the same reasons as for keratometry.

PVA

Potential Visual Acuity. Irregularities in corneal topography ahead of the entrance pupil reduce the visual potential of the eye. The consequence of these irregularities are assessed by the calculation of the Surface Regularity Index which has been correlated to PVA in a published clinical study. The PVA is given as the range of best spectacle-corrected Snellen visual acuity that might be expected from a functionally normal eye with the topographical characteristics of the analyzed cornea. Diagnostic evaluation should consider the fact that tear film breakup can greatly influence PVA (and SRI). Prolonged gazing at a fixation target by a patient without blinking can produce tear film breakup, transiently reduced vision, and abnormal values of PVA and SRI. With proper blinking, abnormal values of PVA are associated with true irregular corneal astigmatism as is often observed with keratoconjunctivitis sicca, contact lens warpage, lamellar keratoplasty, and herpes keratitis.

SRI

Surface Regularity Index. The SRI is a correlate to potential visual acuity and is a measure of local fluctuations in central corneal power. When SRI is elevated, the corneal surface ahead of the entrance pupil will be irregular, leading to a reduction in best spectacle-corrected visual acuity. High SRI values are found with dry eyes, contact lens wear, trauma, and penetrating keratoplasty.

SAI

Surface Asymmetry Index. The SAI measures the difference in corneal powers at every ring (180 degrees apart) over the entire corneal surface. The SAI is often higher than normal in keratoconus, penetrating keratoplasty, decentered myopic refractive surgical procedures, trauma, and contact lens warpage. Adequate spectacle correction is often not achieved when SAI is high.

CEI

Corneal Eccentricity Index. The CEI is a measure of corneal eccentricity, a global shape factor. A positive (normal) value is obtained for a prolate surface, a nil value for a sphere and a negative value for an oblate surface. Out of range

values include keratoconus (higher than normal) and negative values often found with contact lens wear and myopic refractive surgical corrections.

SDP

Standard Deviation of corneal Power. The SDP is calculated from the distribution of all corneal powers in a videokeratograph. SDP is often high for keratoconus corneas, transplants, and trauma—all situations in which there is a wide range of powers occurring in the measured topography.

IAI

Irregular Astigmatism Index. The IAI is an area-compensated average summation of inter-ring power variations along every meridian for the entire corneal surface analyzed. The IAI increases as local irregular astigmatism in the corneal surface increases. IAI is high in corneal transplants shortly after surgery. Persistence often heralds suboptimal best spectacle corrected vision.

AA

Analyzed Area. The AA gives the fraction of the corneal area covered by the mires that could be processed by the TMS-2. AA is lower than normal for corneas with gross, irregular astigmatism, which causes the mires to break up and not be resolved. A lower than normal AA is found with early post-op corneal transplants, advanced keratoconus, and trauma. AA can also be artifactually low during a squint or when the eyes are not opened wide.

CVP

Coefficient of Variation of corneal Power. The CVP is calculated from the Standard Deviation of corneal Powers (SDP) divided by the grand average of corneal powers. This fundamental statistic is high when there is a broad range of powers in the corneal surface and has been found to be a good measure of corneal varifocality. High values of CVP are found in moderate to severe keratoconus corneas as well as corneal transplants in the early post-operative period. Manifest refraction of an eye with high CVP will be difficult to achieve, but attention to refraction is important in such a patient to attain spectacle tolerance. The CVP value given has been scaled up by a factor of 1000.

Appendix C
TMS-2™ topographic maps
Information extracted from the Help Menu on TMS-2™

A Standard map shows the paraxial refractive power. Each point on the map is represented by the power of a sphere whose axis and apex is coincident with the axis and apex of the videokeratoscope. This map is a good indicator of both the power and shape of the cornea. It also has the advantage that normal corneas tend to look normal, i.e., a spherical cornea will appear in only one color.

The Refractive map modifies the Standard map to include the effects of spherical aberration. By including spherical aberration, this map is a better indicator of power but all indication of shape is lost.

The Instantaneous map shows shape but all indication of power is lost despite the conversion of the radius of curvature into diopters. The concept of radius of curvature can be understood by considering the difference between bearing to the left and a U-turn. The former has a very large radius of curvature and would be displayed with a low dioptric value. The latter has a very small radius of curvature and would be displayed with a high dioptric value. In corneal topology, keratoconus, for example, has a small radius of curvature and in an IROC map its high would stand out more than in a Standard Map. IROC maps are also useful in PRK. The knee stands out very well in PRK IROC maps.

The Numeric–32 Meridian Map displays color-coded numeric values (diopters or millimeters, whichever was specified in TMS System Configuration) along 32 meridians. With this map, you do not have to refer to a scale to read the dioptric value of a point on the cornea–just read the numeric value off the map.

The Meridional Map displays the power changes over the corneal surface. The steep and flat meridians as reported by the SimK are plotted in the top half of the map, with the difference, in diopters, plotted in the lower half. Each segment of the meridians is color coded according to the Absolute scale. A scale in millimeters showing the length of the meridians runs horizontally through the display and relates to both top and bottom displays. The difference portion of the map has a scale in diopters located on the bottom left of the screen.